BOSTON TRANSPORTATION PLANNING REVIEW

FINAL SUMMARY REPORT
STUDY ELEMENT 6

LAND USE AND TRAVEL FORECASTING

DECEMBER, 1972

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I. INTRODUCTION AND SUMMARY

The Study Design for the Boston Transportation Planning Review (BTPR) established a framework for Study Element 6 as follows:

"The objective of this Study Element is to forecast land use (urban activities) and travel patterns to the required degree of disaggregation of small areas, modes, links and time of day, to the accuracy required for deciding between alternative transportation program packages, and to provide evaluations of two basic types:

(1) assessment of the degree to which each alternative furthers regional land development objectives, and

(2) assessment of user costs and benefits.

The work defined here is essential to the evaluation of alternative transportation systems. The assessment of the primary direct benefits of, and therefore the primary justification for, transportation investment -- user time, cost and operating savings -- can be determined in any meaningful way only through the type of work described here. A large proportion of the other benefits and costs, particularly environmental effects, are direct functions of traffic volumes and conditions, and therefore dependent on this work.

All of the work described here is necessary, despite the large amount of land use and travel forecasting work accomplished in recent years, because most of the alternatives being considered have not previously been subjected to analysis and evaluation. The new work builds heavily on that past work, however, and because it does, can be accomplished at a small fraction of the time and cost that would otherwise be required.

The alternatives being studied include a wide variety of different assumptions about speed, price, frequency and convenience of travel service. The design and evaluation criteria which have been proposed for deciding between program packages relate to a very wide set of important issues facing our urban areas. The challenge has been to structure and carry out forecasts of land uses and travel in a

way that is sensitive to the differences among alternatives, the values and criteria generated by the participants in the study process, and sensitive to the need for staged decision making in which several iterations of analyses are needed for comparing alternatives over the period of the study. Because of the use of substantially different methods in this study, and because of the need for understanding of the proposed work by participants with widely varying backgrounds, a rather full explanation of the approach and methodology is presented below before the specific work program is described in the final subsection of this Study Element."

The general framework was responded to in the BTPR Contract with the following language.

"The function of Study Element 6 is two-fold. First is to develop an understanding of transportation needs and problems at a subarea scale; to compose regional networks from subarea alternatives; to test facility interaction sensitivity; to forecast the effects of the alternative transportation systems on the regional patterns of land use and intensity of development; to forecast travel on all parts of the system, taking into account competition among modes, effects of congestion, fares, tolls and parking fees. The above are related to providing all study elements with travel and land use information to assist in the development and evaluation of alternative subarea transportation plans and program packages. In addition, Study Element 6 will provide all other elements with quantitative estimates of traffic flow for each alternative for use in impact measurement. The second and equally important function of this study element is to provide measures of the transportation user costs and benefits associated with each of the alternative transportation plans prepared as a result of Elements 4 and 5 work. These measures of transportation user costs and benefits must be disaggregated to indicate who derives or pays the transportation costs and benefits associated with the alternative transportation, as well as which of the component transportation facilities produce these user costs and benefits. This latter function is critical to the success of this study whose guiding philosophy is the equitable distribution of costs and benefits associated with the provision of transportation facilities."

Tasks specified in the contract to carry out Study Element 6 are as follows:

1. "Review and analyze available zonal transportation demand and land use data.

2. Modify Task 1 1990 travel demands to reflect two alternative assumptions regarding central area 1990 growth, as well as alternative modal split and demand assumptions to reflect the alternative transportation plans under study. These modifications are to be accomplished using growth factor techniques.

3. Using the results of Task 2, prepare subarea transportation demand statements using selected link and subarea isolation analysis techniques.

4. Assemble, code and assign travel to regional transportation system alternatives using the Phase I subarea phases developed in Study Element 4 (Transportation System Design).

5. Calculate and prepare a report measuring the transportation user costs and benefits associated with each of the Phase I alternative subarea plans. These calculations will show the distribution of these costs and benefits by zone of trip origin, group of travelers, zone of trip destination and by proposed facility within each subarea alternative. These calculations will be based on the travel estimates prepared in Task 2 and will explicitly consider the costs associated with goods movement.

6. Implement the cross elasticity model described on pages 6-15 to 6-20 of the Study Design.

7. Estimate the 1980-1990 land use consequences of Phase II alternative systems.

8. Calculate 1980 and 1990 travel demands by mode using the model referred to in Task 6 for each of the Phase II alternatives. In addition, prepare estimates of the magnitude and distribution of transport user costs and benefits associated with each plan.

9. Prepare final land use and transportation demand estimates for 1990 for the evaluation of the recommended Phase III transportation system.

10. Prepare a final summary report describing the analysis and findings resulting from this study element.

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[1] The last regionwide transportation system study done for the Boston Area. It was complete in July, 1970.

This final summary report, prepared in Task 10, will deal primarily with methods and procedures for analysis and methodological findings. Forecast results are reported only where they illustrate some methodological point. Forecast results are contained in the many BTPR reports and memoranda.

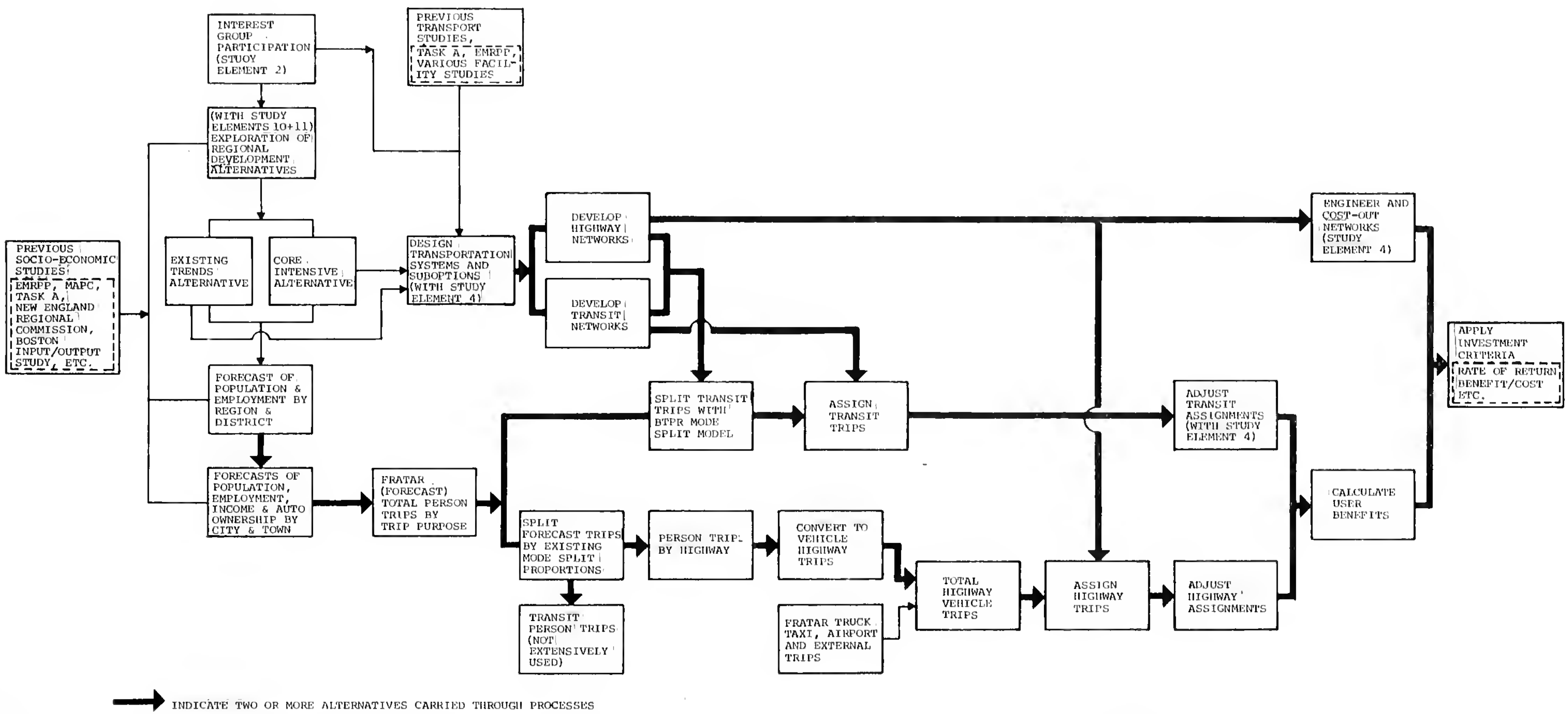
Procedures adapted for use in the BTPR were kept as simple as possible for several reasons. First, there was the necessity to explain them to participants. Complex modeling procedures would have been more difficult to explain, and therefore would have produced results more uncertain of encouraging confidence and consensus. This is a very important issue in an open participatory planning process. Second, many of the procedures had to be repeated many times because of the iterative alternative exploring nature of the process. Different assumptions, systems and sub-systems were constantly being tested and refined in the BTPR.

A third reason for employing simple procedures was that the existing data base had to be used. While this base was quite ample, since several studies had been conducted leading up to the BTPR, it was somewhat dated, implying diminishing returns from attempting to develop new and more complex forecasting methods. A fourth reason was that procedures development is rather costly. While a fairly generous budget was provided for Study Element 6 (700,000 dollars estimated in the Study Design), the large number of alternatives and sub-options required that most of the resources be devoted to actual forecasting and analysis.

The fifth reason for keeping procedures as simple as possible was that land use and travel forecasting was intended to play a much smaller role in the BTPR than it has in more traditional transportation studies. The calculation of transport benefits was only one of many pieces of evaluation information. The last reason for simplicity was that "hand intervention" at various points in the analyses was desirable. Adjustments had to be made to update obsolete data, and for the purpose of examing some situations in detail. Intervention is easier with simple, than with complex, procedures.

A flow diagram of the procedures and their general sequence is shown in Figure 1. The final output from the process is the transportation investment criteria information. Information produced throughout the process is used for a variety of pur-

FIG. 1 FLOW DIAGRAM OF OVERALL LAND USE/TRAVEL FORECASTING PROCEDURES



poses. For example, population and employment data are used for economic impact evaluations. Travel estimates are used for air, water and noise pollution impact estimates. Study Element 6 data provided an important set of data on the description and performance of the transportation facilities under study. In addition it collected a store of socio-economic data basic to all general and specific, long and short term planning. Data collected included the U.S. Census of Housing and Population, travel patterns from several sources, facilities descriptions, base maps and employment and income data from several sources.

The base year for travel forecasting was 1963. The last comprehensive inventory of facilities and patterns was taken then. This data was supplemented with more recent information where available. The socio-economic base year was 1970, the U.S. Census of population year. Ninteen- hundred and sixty-nine was the last year for which city and town summaries of employment could be obtained. For some purposes 1967 employment data was used because it was considered more "normal" than 1969. Ninteen-hundred and sixty-three was also the date of the last area-wide land use survey. As mentioned, from the outset BTPR was committed to the use of secondary data sources. Data was updated by survey only where it was important and existing data clearly out-of-date.

Phase I of the BTPR, lasting approximately from August to December of 1971, was a period of developing alternatives from existing proposals and information. For Study Element 6, Phase I involved collecting, sorting and displaying travel data and forecasts prepared previously. Phase I also required that work begin on defining and coding BTPR transport analysis networks, and on exploring various procedures for transport demand analysis. It was clear that the central transport data processing device would be the TRIPS computer program package of Alan M. Voorhees and Associates, the prime contractor for the BTPR. TRIPS is a very comprehensive flexible computer software package which allows additional routines to be integrated into the main body of programs. TRIPS is fully documented in a report the software itself produces.

For Study Element 6 Phases II and III, as the Study Design elaborated them, were blended together somewhat. Each was to have been a complete cycle of design,

simulation and evaluation, with Phase III concentrating in more detail on a single alternative chosen from Phase II. It became clear that the choices could not be made without a great amount of detail, so from January 1972 to January 1973, sets of alternatives were evaluated in great detail. This required that program package evaluations, environmental impact statements and preliminary location designs be produced together. For Study Element 6 this meant that regional systems analyses had to lead rather immediately to detailed facilities analyses. In practice, a procedure was developed in which regional analyses were done for major combination of facilities (alternatives) in each corridor or study area; then detailed study was given to each critical facility involved in a major decision. In the detailed study, quite often, additional regional analyses (assignments) were made. More than fifty regional highway assignments and about twenty transit assignments were done in the course of Phase II and Phase III works.

A brief summary of each of the major analytical steps follows. Procedures are explained in more detail later in this report.

Land Use Forecasting. Establishing a regional framework, and establishing limits for transportation sensitivity analysis, required that overall regional development alternatives be explored. Out of this exploration, conducted with Study Elements 10 (Environmental and Conservation Studies) and 11 (Effects of Alternatives on Regional Economy), with the active participation of Study Element 2 (Community Liason and Technical Assistance), came two regional development alternatives useful for Study Element 6's technical forecasting needs. These were labled the Trends Extended and the Core Intensive regional development alternatives. The process of choosing these alternatives was one primarily of elaborating their consequences in terms of the issues important to the interest groups participating in the BTPR. After exploring several alternatives. . . primarily through discussions and "issue papers". . . it was found that two limiting alternatives. . . one stressing further regional decentralization, and one stressing a reversal of trends, resulting in regional recentralization. . . could encompass the issues and technical requirements of the BTPR. Two additional alternatives were defined for conceptual completeness which fell between the two limiting cases.* For

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*They were really recombinations of the employment and population patterns of the two limiting alternatives.

transportation system testing only the two limiting cases were completely dimensioned and used for travel forecasting.

After establishing the two limiting regional patterns each was generally dimensional in a process of allocation by ring and district, and then more specifically dimensioned by allocating population and employment to cities and towns (and communities of the larger cities). In the allocation process regional control figures for population and employment were tentatively established through use of the most recent studies and data available; then city and town figures available from previous regionwide studies, most importantly TASK A, the Metropolitan Area Planning Council (MAPC) and Transportation Staging Impact Study, Economic Base Study, and the Eastern Mass. Regional Planning Project (EMRPP) were used. Another important imput was the series of local master plan studies done for communities in the study area. Of special interest were the holding capacities for population reported in these studies. These, as clear indications of local policies, were honored unless the existing regionwide studies and 1970 census data showed them to be unrealistically low.

A systematic model such as EMPIRIC or PLUM was not formally used to forecast land use, and more specifically to determine the consequences of changed transportation service levels on the location of urban activities. The EMPIRIC model results from previous studies in the Boston area were consulted in settling on forecast city and town population and employment levels. The problems of determining changed transportation service levels impacts on urban activity locations was handled in a judgmental manner on a site by site basis in Study Elements 11 and 13 (Business Relocation and Employment).

Two forecast years were chosen. . . 1980 and 1995. Nineteen-hundred and ninety-five, for which a lesser amount of forecast information was produced, was selected because federal aid requirements call for 20 year future estimates of transportation service levels.

Travel Forecasting. The normal procedures of forecasting trip generation, distribution, mode split and assignment were followed in the BTPR. Trip generation and distribution were done together in a fratar-type expansion of the 1963 survey data.

Person trips, disaggregated into four trip purpose categories, were fratared to 1980 and to 1995 for the two land use alternatives. Trip purposes used were 1) Home based work trips, 2) Home based shopping, personal business and social/recreation trips, 3) Home based school trips, and 4) non-home based trips. Each category of trip purpose was factored separately according to trip generation equations worked out in the prior TASK A Study.

All person trips were combined and split into highway trips and transit trips, using the 1963 zone to zone[1] mode split proportions. This produced a basic set of highway trips to which other highway trips were added (e.g. taxis, trucks, airport and external trips). The transit trip table produced in this procedure was not used for very much in the BTPR. Another procedure, operating on the zone to zone total person trip forecast, was developed and used to analyze transit demands.

The BTPR mode split procedure explicitly introduced the comparative service levels provided by alternative highway and transit proposals. The fratar procedure does not do this. It assumes the existing relative levels of service will obtain for the forecast years. Adjustments for this assumption were made for both highway and transit assignments.

The assignment procedure was based on a simple "all or nothing" minimum path rule. Again, post-assignment adjustments to compensate, where necessary, for this assumption were made. An explicit adjustment was made for induced travel on all facilities. A detailed procedure for doing this was developed by the BTPR.

User benefits were calculated from final assignments for each facility in question. User benefits included time savings, vehicle operating cost savings, and accident cost savings. These were compared with estimated facility costs to produce the standard public investment criteria of rates of return on invested capital and

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[1] Five-hundred and twenty-nine internal zones plus 18 external zones were defined for the BTPR analysis from the set of 896 TASK A zones. The BTPR study area for Study Element 6 was identical with the TASK A Study area.

benefit/cost ratios. Estimated facility costs were prepared in Study Element 4 after preliminary engineering studies were done.

A major alternative procedure for travel demand forecasting was investigated by the BTPR. This was the cross elasticity or direct demand model developed by Charles River Associates using standard econometric theory and procedures. It combines the steps of trip generation, distribution and mode split into one conceptual model. Because it is not subject to fixed demand levels from prior analytic steps it is implicitely a land use model as well. That is, it implies that trip generation (a function of the size and location of urban activities) changes in response to changing transportation service levels.

BTPR investigations of the cross-elasticity model showed it to be inappropriate for the particular highly disaggregated needs of the BTPR. A reliable calibration of the model could not be performed at the 529 zone level with the data base and resource constraints of the BTPR. While the model definetly has theoretical properties and potential operational properties of great use in transportation demand forecasting, BTPR had to restrict its use to forecasting induced travel (travel not accounted for in a "fixed" travel demand analysis). Material on the cross elasticity model is included in this report.

The remainder of this report contains excerpted material previously written which documents each of the procedures employed in Study Element 6.

II. PROCEDURES FOR ESTABLISHING A REGIONAL FRAMEWORK FOR LAND USE AND TRAVEL ANALYSES

A. Introduction

Exploration of alternative future urban development patterns has become a traditional exercise in metropolitan transportation planning. Standard practice usually involves manipulation of residential, commercial, industrial, recreational, etc. activities in accordance with some overall schemes which are seen as basic spatial alternatives. Such basic spatial notions as spread city, satellite cities, and linear city generally provide the bases for the various alternatives explored. In some cases, the exploration consists simply of listing advantages and disadvantages of the rather "pure" conceptual schemes. In other cases, the alternatives are developed in some detail, and fairly specific evaluation measures are defined and applied. This can lead to ranking each alternative along each separate evaluation dimension. . .or it can lead to computing composite scores combining the separate evaluation dimensions for each alternative.

There are many problems with this approach. Among these are problems of missing the best or optimal alternative, of weighing objectives, of reducing dimensions to common denominators, of defining appropriate measures, and of relating the whole exercise to interest groups and public policies.

Relating public policies directly to urban development patterns is particularly critical in an open participatory type planning process. Interest groups form around one or another public policy issue and will not be satisfied with technical work until they have sufficient indications of how their particular interests are served or disserved by various proposals. In the sense that such groups are constituents in the overall planning process, their interests must be served by that process. . .at least to the extent that information about how their interests are affected is available to them.

Quite often the range of public policy issues will be somewhat restricted by a given planning study dealing with transportation. Metropolitan scale facilities planning of this type, however, usually requires a definition of the general urban development pattern at some future date or dates;

thereby bringing up the whole range of public policy issues which determine the general pattern. Since all development issues potentially must be dealt with, it is important to sort out which are the prime public policy issues and which are secondary for any given planning study. All important elements must be accounted for somewhere, even if simply dealt with as assumptions and given conditions.

One way of accommodating the potentially diverse interests and technical concerns in an open participatory metropolitan transportation planning process is the definition and use of "development themes".

B. Content of a Development Theme

A development theme consists ultimately of sets of objectives, policies, and impact or consequence statements of the probable results of pursuing the stated policies. Obviously the impacts analyzed will be those of prime interest to the participants as well as those technically and legally required. The issues covered in the technical analyses contained in the statements will then be largely or significantly determined by the "politics" of the participants. Examples of issues covered by the Boston Transportation Planning Review (BTPR) are costs of transportation, transportation user benefits, access to jobs and labor markets, transportation stimulated economic growth, open space preservation, neighborhood disruption, and air and water pollution. Where possible, costs and benefits are disaggregated.

In the actual presentation of the material it is possible to organize it around the development themes or around the issues. The BTPR chose to organize its material primarily around the issues. The four development themes chosen for exploration were then threaded through the discussions of various issues. This further tends to de-emphasize the spatial aspects of the themes. Written statements about the themes are not a primary output of the BTPR. They are rather by-products of the process of exploration. Accordingly, documentation concerning the themes are always considered drafts, and are subject to constant review, criticism and revision.

The table of contents from on draft (dated June 26, 1972) of a development themes paper from the BTPR will serve to further explain the material covered.

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C. Development Themes for the BTPR

Initially six development themes were tentatively outlined by the staff of the BTPR for use. These were derived from conceptual scheme relating density, growth and location as follows.

Core Cities and Inner Suburbs

		Increase in Jobs and Housing	Increase in Jobs Only
	Centralized High Density	1. Environmental Protection Alternative	2. Un-named Alternative
Outlying Suburbs	Moderate Density with Clustering	3. Un-named Alternative	4. Un-named Alternative
Outlying Suburbs	Moderate to Low Density with no Clustering	5. Economic Development Alternative	6. Trends Extended Alternative

The six candidates were chosen because they seemed to be technically realistic and because they seemed to serve the interests of various social groups. If a conceivable alternative did not meet these two criteria it was rejected. Several additional alternatives based on higher regional rates of growth than thought possible or likely were rejected at this point.

The six alternatives were then elaborated by BTPR staff and subjected to public review. The review indicated that perhaps as few as two alternatives could suffice to rally and concentrate the various interests and serve the technical needs of the study. In the most general terms these were alternatives of further decentralization of urban activities (labeled trends extended), and a recentralization of urban activities. For lack of a better term this was eventually labeled the core intensive alternative. In further elaboration of the alternatives it was decided to define and work with four alternative development themes. The two additional alternatives are conceptually bracketed by the limiting cases of the trends extended and core intensive

alternatives. Each of the four is however, discrete. Each represents separable bundles of development policies. Diagrams, descriptions and tables explaining the alternative development themes are contained on the following pages.

A listing of the active participants in the BTPR will help to further explain why and how these particular development themes were chosen. The groups are:

PRIVATE INTEREST GROUPS

Action for Boston Community Development
Boston Society of Architects
Greater Boston Chamber of Commerce
Greater Boston Committee on the Transportation Crisis
Boston Society of Civil Engineers
- American Society of Civil Engineers
- Consulting Engineers of New England

Environmental Coalition
International Union of Operating Engineers-Local 4
League of Women Voters
Massachusetts Association of Transportation Constructors
Massachusetts Federation for Fair Housing and Equal Rights
Operation STOP
Sierra Club

STATE EXECUTIVE AGENCIES

Massachusetts Bay Transportation Authority
Massachusetts Department of Public Works
Massachusetts Port Authority
Metropolitan District Commission
Massachusetts Department of Community Affairs

MUNICIPALITIES

Arlington
Boston
Brookline
Cambridge
Canton
Dedham
Medford
Milton
Somerville

REGIONAL (NON-STATE) AGENCY

Metropolitan Area Planning Council

STATE LEGISLATURE

Joint Legislative Committee on Transportation

FEDERAL AGENCIES

Federal Highway Administration
Federal Reserve Bank of Boston

Of these, the most active special interset groups in shaping the development themes were the Greater Boston Committee on the Transportation Crisis, Operation STOP, The Mass. Federation for Fair Housing and Equal Rights, The Environmental Coalition, The Sierra Club, The Mass. Association of Transportation Constructors and the Greater Boston Chamber of Commerce. The most active local groups were the municipalities of Boston, Cambridge, Brookline, Somerville, Dedham, Canton and Milton and the Metropolitan Area Planning Council. State agencies participating regularly in the development themes work were The Mass. Bay Transportation Authority (public transportation), The Mass. Department of Public Works (highways and waterways), The Metropolitan District Commission (water, sewer, recreation and parkways), and the Mass. Port Authority (seaport facilities, airports and one important highway bridge). Active federal agencies were the Federal Highway Administration and the Federal Reserve Bank of Boston.

The primary voice was accorded to the non-public special interest groups and to the local municipalities. It was felt necessary that each interest group be able to identify itself with one or more of the development themes. As a correlary, in the exposition of the development themes it was necessary to identify how each of the interests related to each theme. This was not entirely a staff job. On frequent occasion an interest group would "locate" itself with respect to the themes by means of written reviews and critiques. Appropriate revisions were then made. Development themes are then, living changing concepts.

The same general requirements for forecasting and/or systems simulation obtained for the development themes as for the more traditional approach. Regional control figures for population, income and employment had to be determined for future years. These had to be allocated throughout the region to small areas for alternative patterns. Forecasting procedures are covered later in this report.

The four alternative development themes selected were:

1. Trends Extended; largely decentralization of all activities.
2. Trends Extended; but with suburban clusters of pop. and emply.
3. Core Intensive for emply., but trends extended for pop. with suburban population clustering.
4. Core Intensive; largely recentralization of pop. and emply.

These were not developed to the level of detail common in a traditional metropolitan planning study. They remain general, indicating broad future directions and bundles of policies for development. Their broadest features are:

- <u>Trends Extended; Decentralization without clustering</u>
  This alternative assumes that the past trends that have occured in the Boston metropolitan area will continue into the future. Population will continue to decline in the core cities, stabilize in the inner suburbs, and increase sharply in the Route 128 and Route 495 suburbs. Employment will show slight increase in the central cities, particularly in the central business district of Boston and in the City of Cambridge. Employment will grow most sharply, however, in the suburbs beyond Route 128. This employment implies an increasing concentration of low and lower middle income families in the central cities, with increasing concentration of new jobs in suburban communities. It further assumes that the existing tax structure and other plan implementing measures will remain unchanged in the future.

- <u>Trends Extended; Nodal Concentrations or Clusters</u>
  Though assuming the same distributions of population and employment, this alternative recognizes the wasteful use of suburban land. In the alternative population and employment are concentrated at nodes in suburban areas, particularly in the band between Routes 128 and 495. These nodes range from relatively small clusters. . .such as Planned Unit Developments. . .through new towns both large and small. These new towns would add a new dimension to metropolitan living and actually build upon the trend in very recent years toward somewhat higher densities in suburban areas. They further offer the opportunity,

by concentrating population, of extending line haul rapid transit into suburban areas, serving the concentrations of population grouped around them. The new densities allow opportunities for low and lower middle income housing in suburban areas.

- <u>Core Intensive; Employment Only</u>

  This alternative recognizes the unique characteristics of Boston's core. . .particularly the downtown, but also the immediately surrounding areas and inner parts of Brookline, Cambridge and Somerville. Building on the announced City of Boston policy, it assumes as a target a high level of employment in the central cities, particularly Boston, as a clear alternative the metropolitan area could achieve. Boston possesses one of the most unique core areas in the nation. . .a combination of a close-in airport, a downtown which is a regional center for the six New England States, several of the more important educational institutions in the United States, as well as a host of others, and one of the most important medical complexes in the country. This alternative proposes building on these assets to maintain and enhance central city strength. Employment would still grow outside the central cities, but not at the rate envisioned for the first two alternatives.

  Implicit to this alternative is a major policy change on the part of both state and city governments. Among these changes are: intensive use of all vacant sites for employment development, the creation of a state urban development corporation, write-down of land in the development process. It further accepts the trend of population moving to suburban areas, but concentrates, as in the second alternative, suburban population in nodes at strategic locations.

- <u>Core Intensive: Employment and Population</u>

  This alternative further recognizes the special characteristics of the central cities in assuming that it will be possible to attract population as well as employment back. It attempts to build on some

changing patterns in today's world. . . particularly in an area such as Boston. . .where people marry later and have children at an older age. These people seek a special life style which only such environmentally attractive cities as Boston can provide. Originally attracted by the universities nd other institutions, they tend to stay in the metropolitan area, and provide an unusual opportunity for a housing market. The attraction of in-city jobs makes it even more possible to attract and hold such persons in the city. Further, Boston, Cambridge, Somerville and Brookline posses certain neighborhoods unique in American cities. . .older ethnic neighborhoods which have survived with vitality. These, too, can serve as a basis for a revitalization of the whole inner city area.

Distributions of population and employment for each of these alternatives are shown below. Maps generally depicting them are shown on following pages. In Figures 6, 7 and 8 following the maps, charts are presented which show how the four development themes generally related to alternative transportation investment programs; and how these, in turn, affect the issues of interest to various participants. In the draft papers covering the themes these effects are detailed with respect to the various public policies required.

DISTRIBUTION OF POPULATION AND EMPLOYMENT

FOR FOUR ALTERNATIVE DEVELOPMENT THEMES

			POPULATION 1980			
	1960	1970	Trends Extended: Spread City	Trends Extended: Nodal Concentrations	Core Intensive: Emply. Only	Core Intensive: Emply. & Pop.
Core Cities	968.4	887.7	859.5	859.5	859.5	923.3
Inner Suburbs	732.7	757.9	772.5	772.5	772.5	818.5
Route 128 Suburbs	592.3	697.3	818.9	818.9	818.9	769.3
Route 128,495 Suburbs	228.3	385.5	487.8	487.8	487.8	427.6
Route 495 Suburbs	869.8	1097.5	1370.5	1370.5	1370.5	1370.5
TOTAL	3451.5	3825.9	3825.9	4309.2	4309.2	4309.2

DISTRIBUTION OF POPULATION AND EMPLOYMENT
FOR FOUR ALTERNATIVE DEVELOPMENT THEMES

EMPLOYMENT

			1980			
	1963	1969	Trends Extended: Spread City	Trends Extended: Nodal Concentrations	Core Intensive: Emply. Only	Core Intensive: Emply. & Pop.
Core Cities	555.0	613.5	657.7	657.7	787.5	787.5
Inner Suburbs	187.2	201.7	234.2	234.2	246.5	246.5
Route 128 Suburbs	194.5	279.5	318.4	318.4	303.5	303.5
Route 128,495 Suburbs	102.5	134.7	186.2	186.2	151.7	151.7
Route 495 Suburbs	256.6	317.3	485.5	485.5	392.8	392.8
TOTAL	1293.8	1552.7	1882.0	1882.0	1882.0	1882.0

KEY

For Illustration the anticipated increase in population and jobs are shown distributed by town :

•= 1 new person per 4 developable acres

○= 1 less person per 4 developable acres

▲= 1 new job per 4 developable acres

TRENDS EXTENDED DEVELOPMENT PATTERN

FIG. 2

BTPR REGION 0 1 2 3 4 5 10 MILES

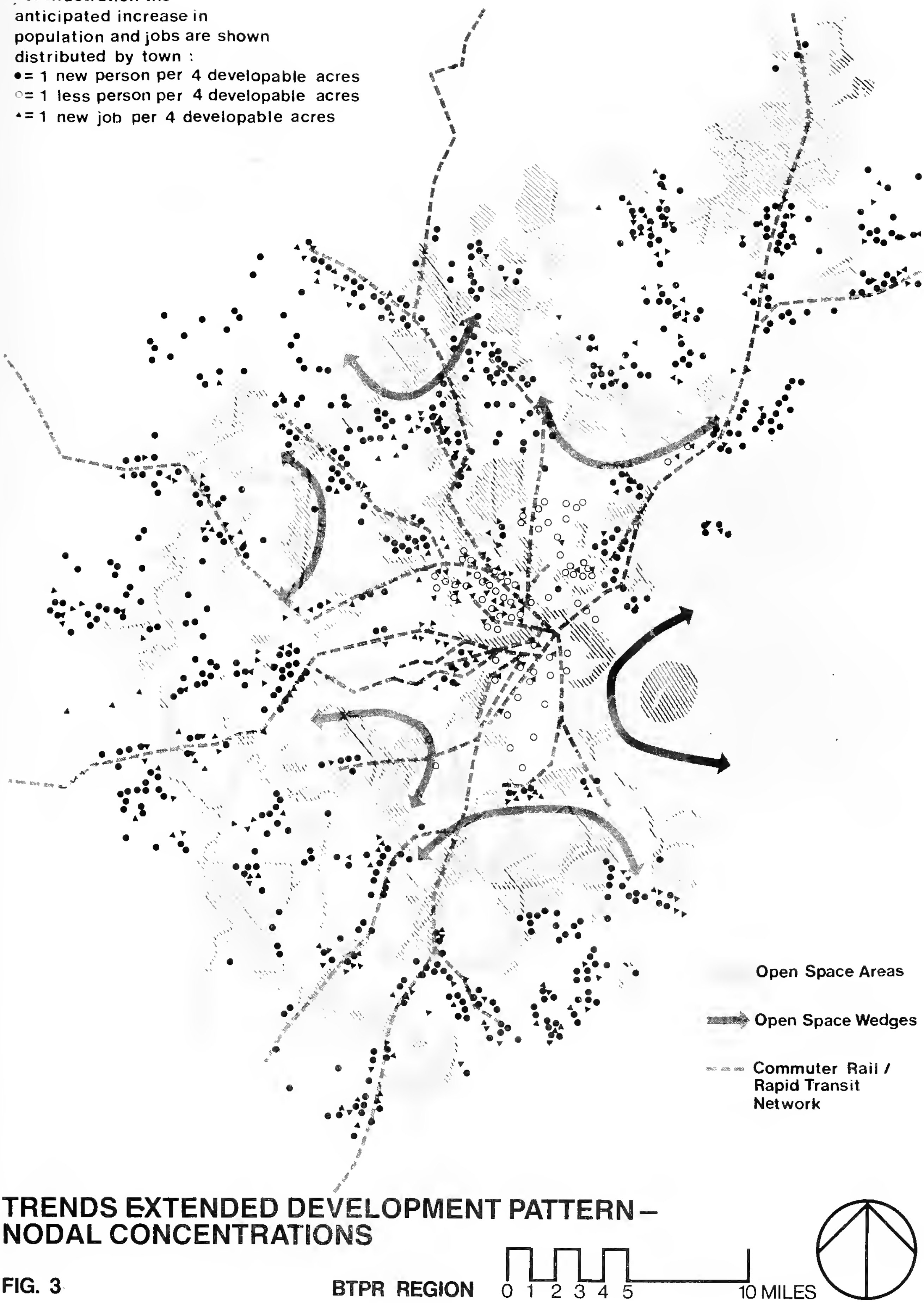
KEY

For Illustration the anticipated increase in population and jobs are shown distributed by town :

•= 1 new person per 4 developable acres

○= 1 less person per 4 developable acres

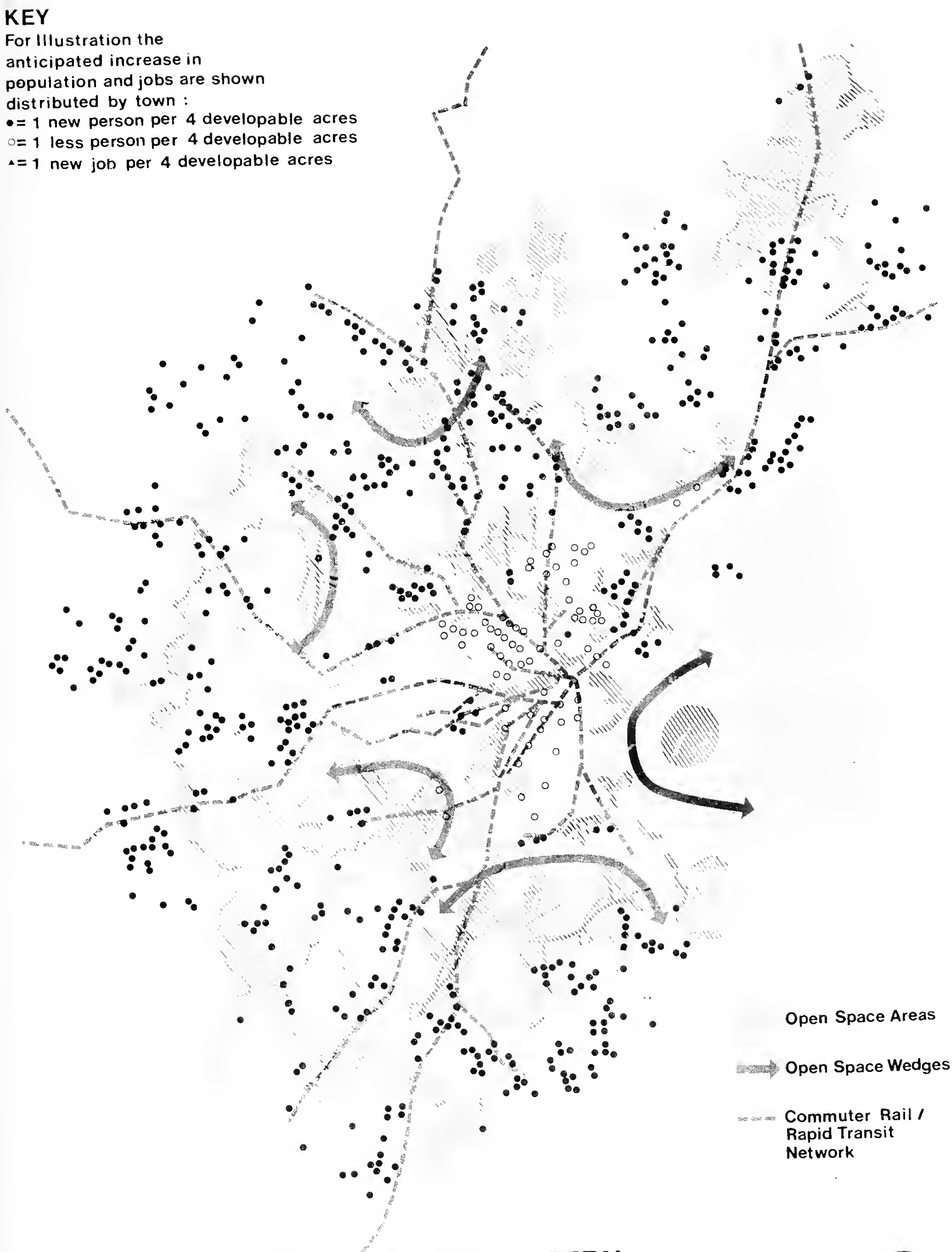
▲= 1 new job per 4 developable acres



TRENDS EXTENDED DEVELOPMENT PATTERN – NODAL CONCENTRATIONS

FIG. 3

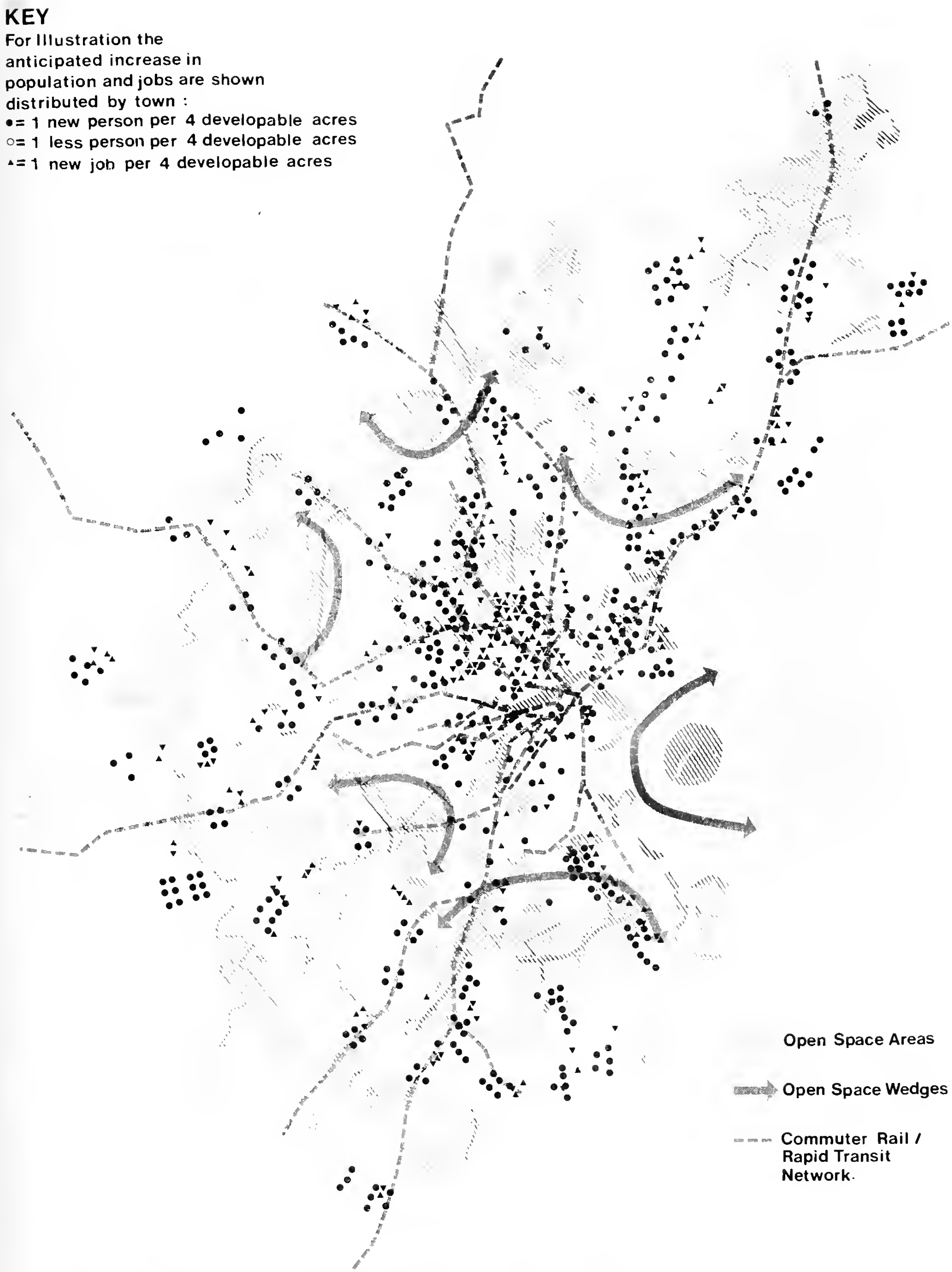
BTPR REGION



CORE INTENSIVE DEVELOPMENT PATTERN – EMPLOYMENT

FIG. 4

BTPR REGION 0 1 2 3 4 5 10 MILES



CORE INTENSIVE DEVELOPMENT PATTERN – EMPLOYMENT AND POPULATION

FIG. 5

BTPR REGION 0 1 2 3 4 5 10 MILES

FIGURE 6

RELATIONSHIP OF REGIONAL DEVELOPMENT THEMES AND
ALTERNATIVE TRANSPORTATION PROGRAMS

A L T E R N A T I V E   T R A N S P O R T A T I O N   P R O G R A M S

REGIONAL DEVELOPMENT THEMES	Max. Serv. by 6 lane Highways Limited Transit Impvts.	Small scale Highways, 4 lane max. More Transit Impvts.	Core by-pass Service, Non Core oriented hwy. incr. Core oriented transit	Serv. to non core tvl. by hwy. outside core, Incr. core oriented transit	Special Purpose hwys. max. transit Impvts.	No major highway impvts. max. transit Impvts.
Alternative 1 Trends Extended		X X X X X X X X X X X X X X X X X				
Alternative 2 Trends Extended: Nodal concentrations		X X X X X X X X X X X X X X X X X X X X X X				
Alternative 3 Core Intensive: Emply.			X X X X X X X X X X X X X X X X X X	X X X X X X X X X X X X X X X X X		
Alternative 4 Core Intensive: Emply. and Pop.					X X X X X X X X X X X X X X	

Legend:

	Strong positive relationship
X X X X X X X	Moderate positive relationship
	Weak relationship

FIGURE 7

RELATIONSHIP OF REGIONAL ISSUES TO TRANSPORTATION PROGRAM ALTERNATIVES

REGIONAL ISSUES	ALTERNATIVE TRANSPORTATION PROGRAMS: Max. Serv. by 6 lane Highways, Limited Transit Impvts.	Small scale Highways, 4 lane max. More Transit Impvts.	Core by-pass service, non core oriented hwy. incr. core oriented transit	Serv. to non core tvl. by hwy. outside core, Incr. core oriented transit	Special purpose hwys. Max. Transit Impvts.	No major Highway impvts. Max. Transit Impvts.
Water Availability	--	--		-	++	++
Air Pollution	---	--	-	-	++	++
Open Space	--	--		-	++	++
Vacant Land	---	-		-	++	++
Quality of Life	---	---	+	+	++	+++
Goods Movement	+++	+++	++	++	---	---
Service Economy	+	+	++	++	++	++
Downtown	-	-	+++	+	+++	+++
Airport	+++	++	+++	++	--	--
Emply. Growth	+++	++	+++	++	++	++
Transportation Cost	--	--	-	+	++	++
Emply. Access	++	++	++	+++	++	++
Distrib. of Trans. Serv.	-	+			+	-

Legend:

+++ Strong positive relationship — --- Strong negative relationship

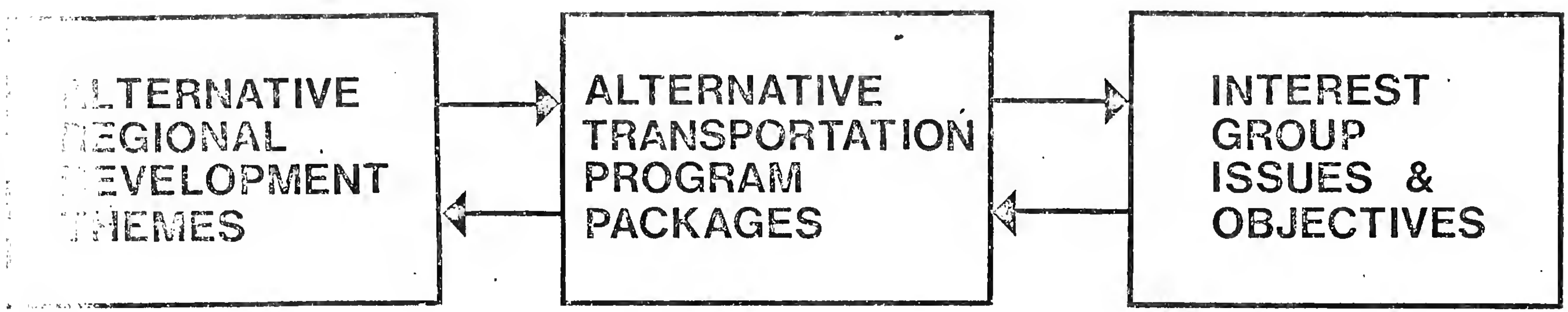
++ Moderate " " — -- Moderate " "

+ Weak " " — - Weak " "

Blank indicates no relationship

Figure 8

THEMES/PROGRAMS/ISSUES/OBJECTIVES CONTINUUM



Alternative program packages are the key to relating individually or group-held interests to overall regional development themes. It is not clear how goals and objectives important to interest groups relate directly to the regional themes. Only general objectives, without much meaning to special interest groups, may be directly stated for the regional themes.

D. Specific use of the regional development themes data

For land use and travel forcasting only the trends extended and core intensive data were used. The prime technical use of the development theme was to set limits on the extent of future transportation demands. The regional themes also served a political "conflict resolution" or "consensus achievement" function of more limited interest to Study Element 6.

III. PROCEDURES FOR SELECTING AND ADAPTING CITY AND TOWN POPULATION AND EMPLOYMENT FORECASTS

A. Introduction

The BTPR selected figures were not produced with a model as were figures from previous studies. BTPR figures are essentially modifications of previous model forecasts. Reasons for not using a model are discussed in this section later. Modifications have been based on more recent survey data (e.g., for city and town master plans), and on judgments about which forecasting assumptions and conditions no longer hold. One set of BTPR selected figures may be thought of as trend extrapolations based on an assessment of existing policies. That is, they are the results of: 1) judgements about the likely consequences of continuing existing policies; and 2) judgements about the strengths of these policies.

The EMRPP and Task A forecasts, which were the primary points of departure for the BTPR selections, both showed population dispersing throughout the region to a slightly lesser extent than the 1960 to 1970 trends show. Consequently, the BTPR figures for population are slightly lower (an average of 7%) than for these two former studies. On the other hand, the BTPR figures for regional population are, on the average, 9% higher than that forecast by MAPC. The 1990 MAPC figure for the BTPR region is only 61,000 higher than the 1970 U.S. Census figure. Population grew in the BTPR region during the 1960-1970 period by an average annual increment of 14,000 people.

Employment growth trends show the opposite effect when compared with this EMRPP and Task A figures. That is, trends as measured from 1963 and 1969 data (adjusted for non-coverage) from the Mass. Division of Employment Securities (DES) indicate much less dispersion than anticipated. The averaged BTPR Regional Series A, B, and C figure for total employment is 25% higher for the BTPR region than the averaged EMRPP and Task A figure. Task A, since it was done later than EMRPP, was adjusted in the right direction, but apparently not enough -- especially for employment.

There is a key distinction to be recognized between slightly modified and

unmodified trends and policies on the one hand, and completely or essentially new or reordered policies on the other. Obviously, a continuum from the simple continuation of existing policies to the promulgation of totally new policies could be defined. However, for BTPR purposes, it was more useful to speak of a dichotomy between what is essentially an extrapolation of current and past conditions, and completely new conditions for the future.

The regional figures for population and employment developed by the BTPR represent an extrapolation of current and past conditions. Some conditions have been slightly modified (e.g., a lowered assumption about the fertility rate to produce a low regional population figure), but not enough to qualify as a really important difference. That is, the "alternative regional future" resulting from this assumption would not be very different from that resulting from a simple extrapolation of the current fertility rate. The regional ranges of population and employment established are therefore "realistic" ranges in the sense that they can be achieved within the context of current trends and policies (perhaps slightly modified).

Examples of the kinds of trends that would have to change in order to alter regional population and employment levels beyond those regional forecast limits selected are: fertility rates doubling or halving; patterns of in and out migrations changing owing to, say, large increases in economic base activities caused, perhaps, by increased federal research and development activities or by a resurgence of manufacturing activities. These trends are, for the most part, beyond the powers of local or state government to control, and therefore must be taken largely as given. For purposes of establishing a dialogue about alternative futures, these trends can be assumed to change.

Examples of public policies that would have to change in order to alter the distribution of population and employment are: the establishment of metropolitan government, methods of real property and income taxation, much accelerated programs of public facilities investment, and accelerated subsidized housing programs in the core cities and/or suburbs. The recent public

policy shift that has occurred in the area of environmental protection <u>has been accounted for in the BTPR trends forecasts</u>. Further, major changes in this policy area could alter the regional distribution of employment, and especially of population. A program of urban development predicated on the single objective of minimizing energy inputs would probably have the greatest effect on redistributing activites. Such an objective argues for greatly increased clustering of activities to achieve scale economies. Environmental programs which exclude urban activities from protected lands have the next greatest distributional impact. Programs which are designed to clean things up (e.g., water and air) or screen out existing undesirable effects (e.g., noise) do not have as strong effects on the location or population and employment.

B. Land Use Modeling

One possibility for land use forecasting, one advocated in the BTPR Study Design, was the use of the EMPIRIC Land Use Model. This possibility was investigated and discarded. The two critical factors were:

1. The model as calibrated for the EMRPP did not reflect the most recent urban development trends. . .trends showing that the process of decentralization was somewhat abating.
2. Requisite data for recalibration of the model was not yet available from the 1970 U.S. Census of Population and Housing.

In addition a model recalibration effort would have diverted some resources away from the already tight schedule of the BTPR.

C. Ring and District Analysis of Population and Employment Distribution

In place of a modeling procedure, it was decided to use a more traditional "hand operated" staged disaggregation of population and employment. The intermediate stages, between the region and city and towns were five rings and ninteen districts.

Rings are areas of reasonably similar urban development and growth character-

istics. The Eastern Massachusetts Regional Planning Project (EMRPP) city and town area was divided into five rings centering on Downtown Boston. The first four of these rings constitute the 74 city and town BTPR region. The outer ring is an area for which data was carried along because much of the transportation information available to the BTPR relates to the EMRPP area, and because the 152 city and towns constitute a more natural area for regional economic analysis than does the BTPR region. For the two alternative futures, population and employment vary only in the first four rings. The outer ring was held constant. The map on the next page shows the rings.

The BTPR region was broken down into 19 analysis districts. These contain an average of 4 cities or towns each. The central ring (the core) is the largest of the 19 analysis districts, and for the BTPR, strategically the most important in terms of the alternative development concepts. Two concepts are used... an extension of existing trends, and reintensification of the core.

Analysis started from the existing trends situation. BTPR reviewed several sets of projections as well as master plan studies for each city and town before choosing "most likely" population and employment figures for 1980 and 1990. These were summed into analysis districts and rings. Growth rates by ring were then computed for both past and future years. These became the point of departure for determing the growth rates by ring for the core intensive alternative future. Ring growth rates were applied to constituent districts.

Because the whole operation at this point was an intermediate or framework establishing step on the path toward developing city and town figures, general indicative growth rates were all that were needed.

Growth rates were selected in different ways. For the inner and Route 128 suburban rings, factors of two were somewhat arbitrarily selected to transform the population growth rates for the 1960-1970 period into 1970-1980 growth rates. The inner suburban rate was doubled, while the Route 128 rate was halved.

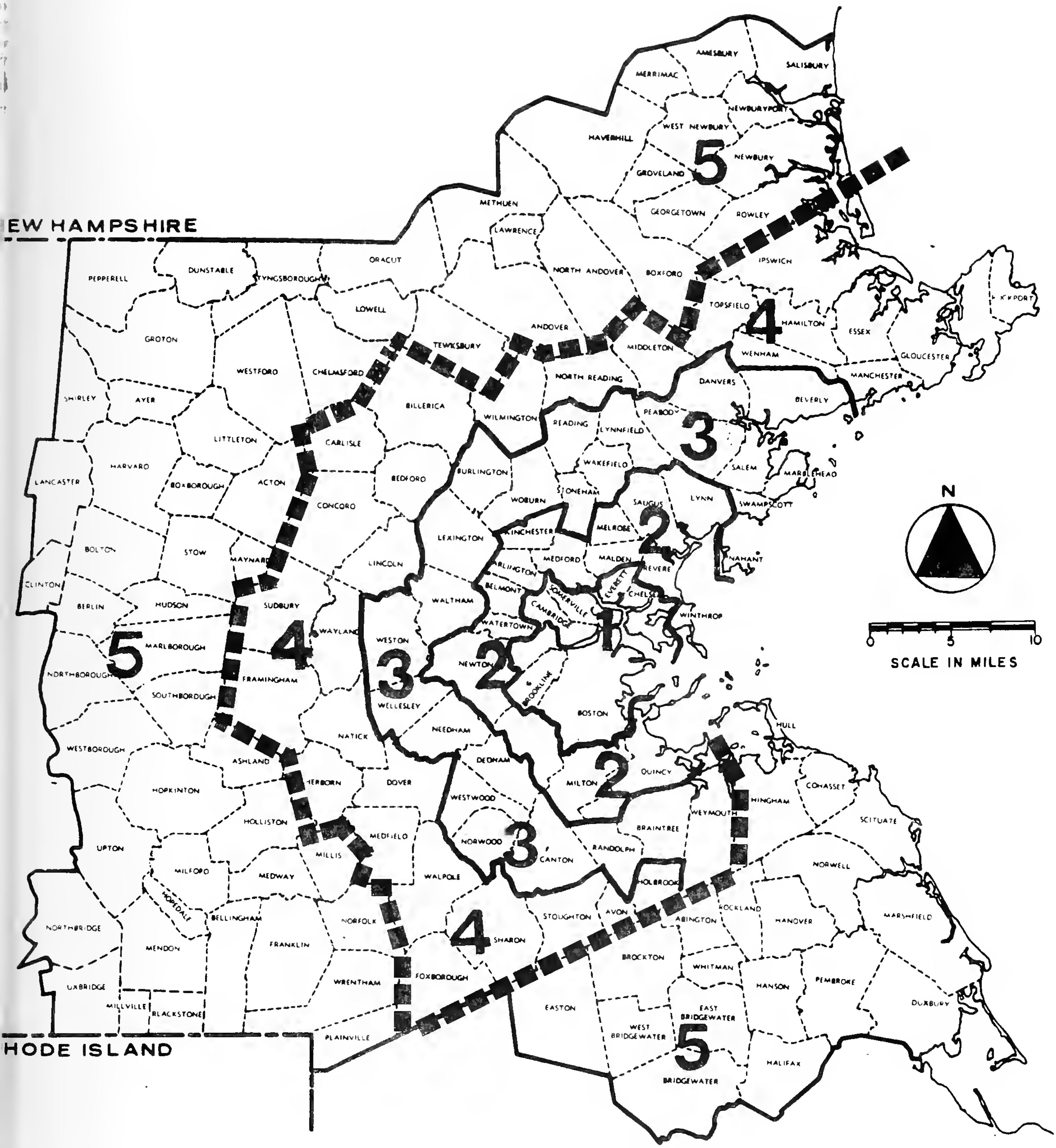


FIG. 8

A N A L Y S I S   R I N G S

BTPR Region Boundary

Ring boundary

1. Core
2. Inner suburbs
3. Route 128 Suburbs
4. Outer BTPR Suburbs
5. Furthest Suburbs

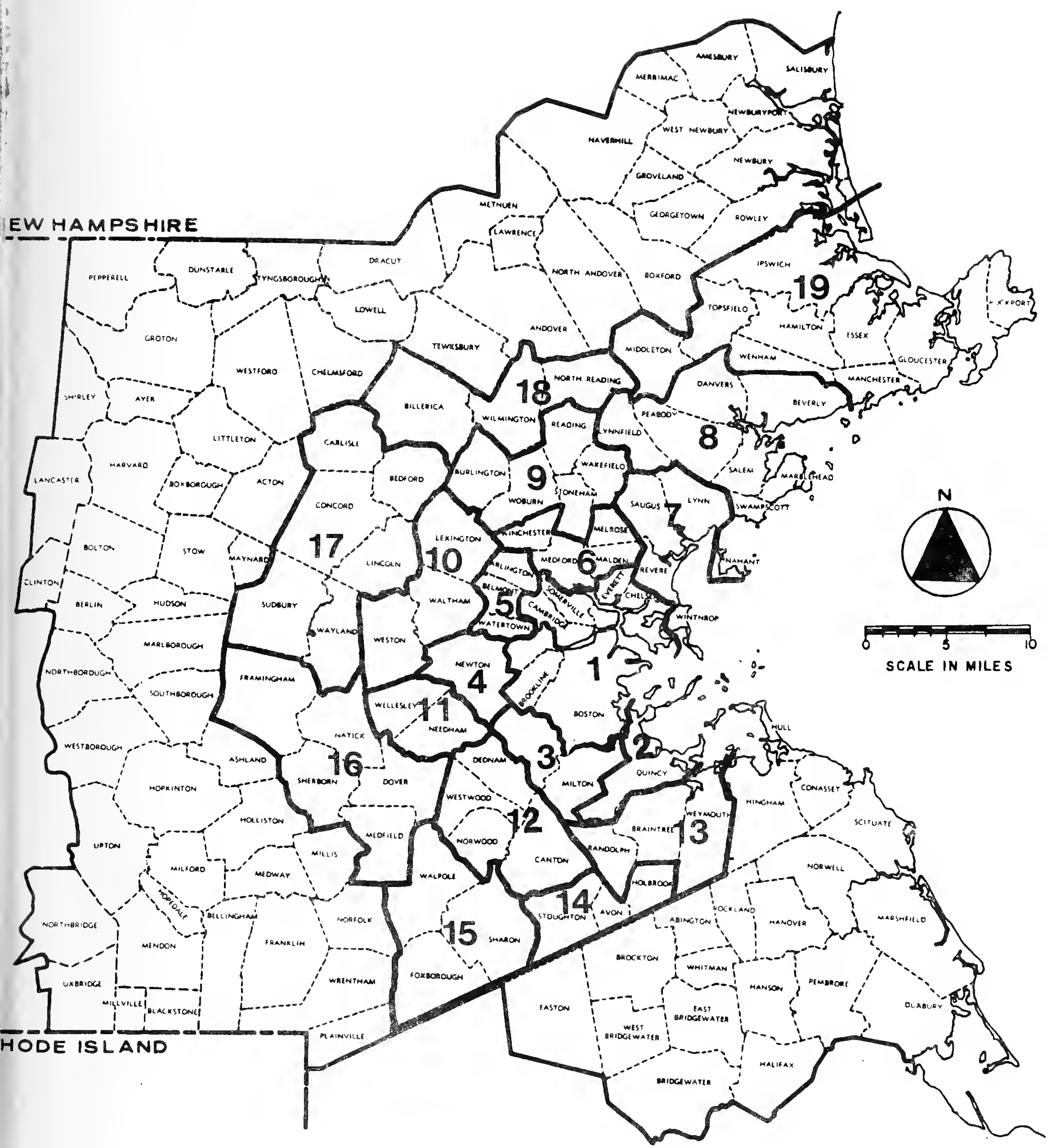


FIG. 9

ANALYSIS DISTRICTS

Analysis District Boundary

The core presented the problem of turning a declining population growth rate into an increasing rate. The figure chosen (+4%) represents a net change of 12% from the 1960-70 growth rate (-8%), and a net change of 8% from the existing trends projected growth rate of -4% for the 1970-80 period. This was thought to be about the maximum change from existing trends that could occur. The population figure derived from this calculation agrees very well with a target of 675,000 set by the City of Boston itself. Doubling of the existing trends projected employment growth rate for 1970-80 also produces a core figure which corresponds very well with City of Boston's 1980 employment target of 618,000.

The outer BTPR suburban ring (#4) growth rates resulted from prior determinations for the inner 3 rings and keeping to regional "control" figures for the BTPR region. Growth rates for the furthest ring (outside the BTPR region) were not altered between alternative futures. For the BTPR work, this area was carried along but not studied very intensively. The furthest ring contributes relatively little travel on the facilities inside Route 128 under study by the BTPR.

The whole exercise is a way of beginning to define a core intensive alternative future. In the process of further defining that future, some adjustments at the city and town level were made to the data. After these adjustments were made, the data were used to compute trip ends by traffic zones for 1980 (and subsequently for 1995) for purposes of assessing future travel demands.

Highlights of the core intensive alternative future, when viewed at the ring level of analysis for population, are:

- The core still does not return to its 1950 levels of population. . . even by 1990. It does surpass its 1950 employment level by 1980 in both alternative futures.

- By 1980 in the Core Intensive future, 9% more population is allocated to the core than in the Existing Trends future. By 1990, this figure becomes 21%. This is a fairly substantial difference and could be

enough to rebuild the market for public transportation to the point where both major new line haul and coverage intensive investments could be justified.

- Between 1980 and 1990, the growth rates of each ring come out to be about equal. This is simply a consequence of the method. It is not a necessary assumption or something felt to be desirable or undesirable.

- The most significant feature of the Core Intensive future is its shift of population to the core. To accomplish this shift, all of the major factors now contributing to decline must be shifted also. These include appropriate job creation in the core, and decreasing the urban-suburban disparities between relative taxing and urban service levels (especially education, pollution, transportation, protection and recreation). Moreover, the provision of appropriately priced and adequate housing in the core is essential to its reintensification.

- While the population growth figures say nothing of the composition of the population, it is clear that the magnitude of growth contemplated in the Core Intensive future requires retention of low income families <u>and</u> attraction of middle and upper income families back into the core. Programs to retain low income families in the core will inevitably conflict with current programs to scatter low income families in suburban areas. Programs to attract middle and upper income families back into the core will have to concentrate on making core areas more competitive, and not too costly, in key urban services.

Suburbanization has resulted in a diffusion of some qualities of accessibility and urbanity...two features that have historically weighed in favor of core areas. Quality shopping streets, higher density living, good hotels, restaurants, and entertainment have all come to suburbia. Reversing the core population decline then, faces the additional burden of overcoming those qualities of accessibility and urbanity already achieved in the suburbs.

Highlights of the Core Intensive future for employment at the ring level of

analysis are:

- The core exceeds its 1950 level in the early '70's. The post-1950 decline was reversed by 1963.

- It was assumed that the core might, optimistically, be able to double its employment growth rate over that predicted for the existing trends situation. This means the core would grow by 16% during the period 1969-80, and drop slightly to a 12% growth rate during the 1980-1990 decade. While the two figures might be reversed, based on the assumption of a slower acceleration to the larger growth rate; for transportation analysis purposes, it is more desirable to assume as large a figure as possible for the network testing year of 1980.

- As with population, the employment figures are based approximately on changes of growth rates by a factor of two. However, the inner suburbs are assumed to increase their employment growth rate by a factor of only 1.5. To have doubled their growth rate would have reduced employment in the Route 128 suburban and outer BTPR rings below their 1969 levels. It was felt more important to allow the core to double its growth rate.

- The Route 128 suburbs halve their employment growth rate. This result requires rather stringent controls on the part of the suburban communities involved. While they would continue to grow, they would have to be rather selective about which employers could expand or locate in their community.

- The outer BTPR suburban ring decreases its employment growth rate, on the average for the two future time periods, by slightly more than one half. As with population, these figures are a result of first determining the other ring growth rates and honoring the regional control figures.

- The assumed core intensive employment growth rate is very close to

the projected regional employment growth rate. The difference between alternative futures must be made up largely of non-service employment, since the core growth rate for service is currently higher than the regional service employment growth rate. From 1963 to 1969 the core service employment rate was slightly more than twice the regional rate. This implies that manufacturing and construction and wholesaling and retailing jobs must be attracted into the core. Currently these activities are growing three times faster in non-core areas than in the core.

- By 1980 the core intensive alternative future allocates 7.0% more employment to the core than does the existing trends alternative. By 1990, this figure becomes 12.5%. These differences are not as large as those for population, primarily because the existing trends for population are more in the direction of regional dispersal.

E. Existing Trends City and Town Population and Employment Forecast Estimates

Various population forecasts and estimates were reviewed for all communities (cities and towns and Boston neighborhoods) and a "working" set of estimates for 1980 and 1990 were selected. Two separate selection processes were gone through and are reported here. The second round selections resulted in the "working" set of data.

The first round selection consisted of choosing one of three previous forecasts made. These were the unconstrained EMRPP Plan C (maximum highway), MAPC and TASK A forecasts. Selections were based primarily on how close each forecast came to the trend shown in the 1960-1970 U.S. Census of Population. None of the forecasts reviewed in this procedure enjoyed the benefit of 1970 U.S. Census data. These first round elections resulted in TASK A forecasts being chosen 39 times; EMRPP forecasts being chosen 18 times; and MAPC forecasts being chosen 12 times. There is a bias in these selections because of decision rule was incorporated to favor TASK A and EMRPP forecasts (if they seemed reasonable in view of 1960 and 1970 data) since they carried disaggregated traffic zone forecasts with them whereas MAPC forecasts do not.

The second round selections were based on two additional items of information and were not confined to choosing one of the previously prepared forecasts. Additional information consisted of locally prepared master plan estimates and appraisals of city and town population levels, and constrained (by local zoning) EMRPP Plan c forecasts.

A variety of selection procedures was followed. The simplest case (infrequent) was where all methods conveged on one point ($\pm 5\%$). In general, land holding capacities, where computed in the master plans, were honored...but in some cases breeched slightly if all forecasts were above them. Master plan estimates were not honored if there seemed to be a consensus of the other forecasts, and especially if the master plan estimate was quite old and if it did not consider land holding capacities.

One common procedure for choosing a new forecast number was to take a consensus future trend (if it existed) and adjust it to the 1970 base instead of the 1960 or 1963 base. All 1980 values were interpolated from the 1970-1990 growth line.

Furthermore, EMRPP and TASK A forecasts contain breakdowns by family income groups. MAPC city and town forecasts, on the other hand, have disaggregations by age groups. This information was useful for BTPR Phase I work which relied exclusively on already prepared forecast data.

Figures for total employment were established by city and towns for 1980 and 1990.

Regional control figures were established first in calculating this new employment series. A regional figure of 1,571,000 for 1990 was established first; then, it was broken down into both corridor sub-totals and sub-totals by the following employment categories: (1) manufacturing and other, (2) retail, and (3) finance insurance and real estate and services.

After establishing these controlling figures, a variety of information was

used to allocate the figures to cities and towns. These included known aspirations for increased development (e.g., Boston, Peabody, Lynn, Salem), satisfaction with the existing level of local employment (e.g., Dedham, Belmont), judgments about development potentials of general areas, and past forecasts made by the EMRPP and TASK A. All information was compared with the employment growth between 1963 and 1969. Probably the single most important series of information were the TASK A forecasts. TASK A is the most recent work systematically covering the region. Local master plans were not systematically consulted (as they were for population) because they do not all contain employment forecasts and because forecasting small area employment from a local (non-metropolitan) perspective is much more hazardous than it is for population.

F. Core Intensive City and Town Population and Employment Forecast Estimate

Establishing the core intensive city and town level forecasts for population and employment was primarily an exercise in trying to reverse the direction of some trends while honoring regional control totals, while retaining as much realism as possible. The City of Boston had established levels. These provided a point of departure for core levels. Other city and town levels were scaled to Boston levels and the growth guidelines established in the ring and district analysis.

One important series of data lending more realism to the exercise was the amount of vacant developable land in the inner suburban areas. It was assumed that redevelopment would be necessary to handle population and employment increases in the core areas, but that this would not be necessary or desirable in the inner suburban areas.

The inner suburbs are an area immediately surrounding the regional urban core. During the 1950-1960 period they grew in population by 6%. During the 1960-1970 period, this rate decreased to 4% growth. The BTPR existing trend alternative contemplates a further reduction of this growth rate to 2% for the 1970-1980 period. The alternative to existing trends projected (the core intensive scheme) calls for a growth of 8% from 1970 to 1980 for the existing suburbs. This is a doubling of the past growth rate.

In view of the relative scarcity of vacant developable land in the inner suburbs, and the desire of the communities themselves to maintain their existing character, the capacities of the vacant land in the suburbs is an important consideration. Information about this issue will partially help to determine whether it might be feasible to double the growth rate of the inner suburbs.

Data shows that the communities of Lynn, Saugus, Malden, Melrose and Milton can absorb their shares of the anticipated population growth required for the doubling growth rate assumption under the condition of trying to maintain their existing character. Two explicit factors used to make this determination are recognition of existing single family detached unit zoned densities, and existing average family size. Allowances in computation of vacant developable land have been made to reserve land for the proposed MAPC Open Space System. Non-developable vacant land additionally includes swamp and other land with poor drainage, land with more than 20% slope, and land with difficult bedrock conditions. Vacant land that is committed to recreation is not considered developable. Ownership of land is <u>not</u> considered a criterion for developability in this analysis.

Vacant developable land in the communities of Revere, Winchester, Belmont, and Quincy must be developed at slightly higher net residential densities in order to receive their increments of growth compatible with an overall doubling of the growth rate. A medium-low density of 12 dwelling units to the acre was used in the analysis. This could be either traditional 2-family houses on 1/6 acre lots, or row houses. For most of these communities, a mix of 12 and 3.5 dwelling units per acre would permit the required population targets to be achieved.

Medium-high residential densities (up to 22 dwelling units per net acre) must be used in the communities of Arlington and Hyde Park if they are to absorb the population allocated to them. This would require garden apartments or low rise mult-family types of units. The communities of Medford,

Newton and West Roxbury must resort to high rise residential development to accommodate the population allocated to them on their vacant developable land. The communities of Watertown and Winthrop, having no remaining vacant developable land, must use land now devoted to other purposes to accommodate more population. One possibility for this is the use of U S. Government land formerly used for military purposes in both towns (the Watertown Arsenal and Fort Heath).

It is possible to fit almost all new population required by the core intensive alternative in the inner suburbs at a low density. 43,000 people could be "fit" on the remaining vacant developable land at an average density of 3.5 dwelling units per acre. This would leave 18,500 people to be fit somewhere else or in the inner suburban ring on redeveloped land (or possibly on some of the MAPC open space land). This pattern of allocation would, however, result in the towns of Saugus and Milton absorbing almost one-third of the total inner suburban ring allotment. These two towns could absorb about 19,000 people at single family detached net residential densities. The character of the town, though, would obviously change. Saugus would lose its "rural" atmosphere with 9,400 new people and no vacant land left. Milton would lose its exurban estate character.

An environmental question, requiring some resolution, that would result from the increased population growth rates in the inner suburbs is the provision of community facilities. The MAPC open space plan does not allow for local facilities such as schools, playgrounds, small parks and recreation centers. Land would have to be reserved for these to accommodate large increments of population growth.

In general, it may be concluded that the inner suburbs can accept an 8% population growth rate to 1980. It will require higher net residential densities in some areas. However, higher densities have already been evidenced in some recent developments in the inner suburbs, and some local officials have expressed a desire for future residential development to be multi-family apartments. Some redistribution of population from the initial allocation for the 1980 core intensive alternative is probably required to recognize the vacant land situation.

G. Relating Transportation Improvements back to Land Use

As mentioned in the summary, relating transportation improvements (derived partially from a land use pattern) back to the land use impacts was essentially on judgmental micro level site by site procedure. One systematic regionwide procedure was followed, however, in which the population and employment accessible within given travel time contours were calculated for different facility proposals. This data served as a proxy for accessibility changes. Data was computed for 1970 and 1980 and provided one data series to help inform judgements about transportation impacts. In some cases there were very noticeable increases in the accessibility so measured.

IV. PROCEDURES FOR REVIEW OF TRAVEL FORECASTS PREPARED PREVIOUSLY

The problem of condensing the network assignments and survey data was solved by plotting the data on a specially prepared simplified network. Plotting was done mechanically.

A set of 89 Districts covering the EMRPP and TASK A region (152 cities and towns) was defined by the BTPR for the purpose of displaying, comparing and analyzing travel forecast data developed by past studies. A "spider" network was then developed to show travel along abstract links connecting centroids for these 89 Districts. The following information has been plotted on these "spider" networks.

- 1963, 24-hour surveyed total person trips.
- 1963, 24-hour surveyed total highway vehicle trips.
- 1963, 24-hour surveyed transit person trips.
- 1963, 3-hour morning peak surveyed total person trips.
- 1963, 3-hour morning peak surveyed total transit person trips.
- 1990, 24-hour EMRPP forecast total person trips.
- 1990, 24-hour EMRPP forecast total highway vehicle trips.
- 1990, 24-hour EMRPP forecast total transit person trips.
- 1990, 24-hour Task A forecast total person trips.
- 1990, 3-hour morning peak Task A forecast total person trips.
- 1990, 3-hour morning peak Task A forecast total transit person trips.

Most of the "spider" network plots show travel from and to selected areas of interest to the BTPR. Sixty-two plots showing transit and highway vehicle travel for 1963 and 1990 have been prepared for 31 high interest areas in each of the three BTPR study corridors. Five additional plots showing all highway and transit travel in the EMRPP and TASK A region were prepared. These were computer-plotted on vellum and are reproducible.

From these regional plots, it is possible to assess the magnitude of change from '63 to '90 and to see how EMRPP forecasts differed from those of TASK A. Since the "spider" network is rather abstract, it only gives a general picture. It is possible only to get an idea of subregional patterns. Detailed analysis of specific travel facilities will have to be based on travel assignments using more detailed trip tables and networks (more districts or zones and links).

Using the plots that show only travel to and from selected areas, it is possible to get an idea of the proportions between local and through traffic, and the connectivity of given areas with other areas.

A. BASIC ASSUMPTIONS AND APPARENT POINTS OF AGREEMENT

The following statements reflect general points of agreement and conclusions that have developed out of the BTPR. These statements define the framework within which transportation proposals can be combined and judged.

- Boston already has a transportation system (a set of expressways, arterials, public transportation services, etc.) -- one prime purpose of the BTPR is to come up with realistic proposals to improve or add to this system so that it will work better now and in the forseeable future. (There is another purpose implied by this -- that is to make a "searching reassessment" of the role transportation should play in the future of the region and what kind of new and different approaches should be created and implemented.)

- The core of the region is expected to remain strong and vital. It is expected to remain the focus for the highest volume of travel in the region well into the future. Providing access to the regional core from all parts of the region is important, (but not the only problem that needs to be solved with transportation system improvements). Sub-regional cores, such as Lynn and Salem, are also expected to remain important.

- There appears to be general agreement (reflected in the Governor's Phase I statement) that building additional highway capacity to serve the access requirements of the regional core peak hours for commutation purposes by private automobile does not make sense. Transit services of some kind should play the key role in this.

- There also appears to be in general agreement that the Boston region needs a much improved program for new public transportation services; including special new services to handle the special mobility needs of people who do not have easy access to transportation, many of whom are living in the high density inner city communities. These services are needed in addition to improvements to the MBTA rapid transit/bus system and to the system available to suburban commuters. This problem needs higher priority attention than it has received heretofore.

- There is agreement that the Boston region needs a strong program for improving ways to move goods into, out of, and within a region. This is largely highway dependent -- both special

purpose construction and operational improvements are under consideration.

- Based on the decisions made to date, the major additions considered in the foreseeable future would be a set of alternatives, each with not more than six travel lanes (four general purpose, and two special purpose. The options for system additions would consist of I-95 North, I-95 Relocated, the Third Harbor Crossing, and I-95 South (Boston Inner Belt and the Southwest Expressway) and Western Connector. To limit peak hour commuting, the development of these options into a system may have to be accompanied by policies and programs to (1) control parking pricing and supply in downtown Boston; and (2) to control access and traffic on the expressways themselves.

- It is assumed that the approach to transportation in the Boston region that is evolving out of the BTPR requires that every sector of the region be provided with some form of line-haul transit service to the core. At a minimum, this service should at least be improvements in service levels on the facilities that exist today.

- It is generally understood that expressways and line-haul transit facilities are not necessarily substitutes for one another. Each functions differently and caters to different kinds of travel. However, this is not to say that radial general purpose expressways and line-haul transit facilities that serve the same corridor or communities may not be competitive, particularly in providing travel service to the core. It is assumed, therefore, in light of the evolving policy to place primary emphasis on public transportation to serve the core, that radial expressway proposals have to be looked at in terms of their potential effects on the market feasibility of transit proposals.

- It is recognized that, as a result of decisions made to date, and the logistics of the region and its parts, any one single transport service approach that would apply a policy or program to all parts of the region does not make sense. The situations in each subregion are too different:

  - In the Northwest subregion, the decision has already been made to drop the major general purpose expressways that were originally on the agenda. While smaller scale or special purpose facilities are still up for consideration, this decision strongly implies that transit in some form is the only major option for providing improved service between these communities and the core of the region.

- In the Southwest subregion where the demand for core-oriented travel appears high, the only new expressway facility being considered in Phase II happens to fall in the same location and serves the same communities through most of its length as the major existing rail line. There is a question of whether the development of both an expressway and rail transit of one form or another would be complementary or competitive. The policy and program options therefore have to take this into account. There is also the question of whether a non-peak hour core-serving facility can be planned.

- In the North Shore, the basic policy and program issues focus on the scale of needs for connections to the core of the region and the relationship of these needs to local transportation improvements. There is an essential question of how much capacity and service to the core is needed, since this subregion has traditionally provided relatively fewer trips to the core than most others. The proposed expressway in the Route I alignment is far enough away from the B&M rail line (the major line-haul transit facility serving the North Shore) so that these facilities are not competitive. In addition, no major transit improvements are under consideration in this corridor. The Lynn Woods alignment may be more competitive, and I-95 Relocated through Revere and East Boston does not run parallel to the existing Blue Line and serve the same communities.

B. CLASSIFICATION OF FACILITY IMPROVEMENTS ON THE BTPR AGENDA

The items that the BTPR has on its agenda at the present time include a wide variety of facilities and service improvement proposals. Some of these are designed as improvements to the existing regional transportation system in response to a regional need (Class A); some are strictly local in nature (Class C); and some can be classified as partially regional and/or local depending on the basic rationale for the proposal and their subsequent operation and combinations in system (Class B). To a large extent, the involvement in any decision on these proposals should reflect its importance as a regional or local issue. To help sort these out, the following is a tentative method of classification of these proposals.

Class A

- Improvements for regionwide service and with regionwide impact (includes connections to core and between subregions).

- Affect more than one set of communities or subarea of the region.

- Involve fundamental decisions that affect another part of the regional system (not just in terms of travel demand relationships, but also market, use and/or funding).

Class B

- Improvements to the region-serving system provided basically for local service reasons.

- Influence primarily felt in one sector of set of communities.

- Not strongly related to the regional system in terms of basically changing its travel use or functions.

Class C

- Improvements of local importance only.

- Influence primarily felt in one sector or set of communities.

- No important relation to regional system.

NORTH SHORE

Class A

- I-95 North from Cutler Circle as part of through system.

    - Route 1 alignment

    - Lynn Woods alignment

- I-95 Relocated.

- Third Harbor Crossing as part of through system.

- I-93/I-95 Connector.

- Any line-haul transit proposals which involve feeding new service into the existing system in the core.

Class B

- I-95 North from Cutler Circle as an extension of the present Northeast Expressway or as an improvement to Route I traffic flows.
- Third Harbor Crossing with access to airport only.
- I-95 Busway from Cutler Circle.
- Commuter rail service improvements.
- Blue Line extension to Vinnin Square or Pines River.
- Airport access -- by new transit technology.

Class C

- Beverly-Salem Bridge.
- Upper North Shore Connectors.
  - To 128
  - To I-95
- Revere Beach Connector, Winthrop Connector.
- Saugus Marsh, if I-95 Lynn Woods not built.
- Arterial upgrading program.
  - Route 1
  - Route C-1
- Local TOPICS, etc.
- Local transit improvements in the North Shore.
  - Bus system improvements
  - Local transit demonstrations

SOUTHWEST AND BOSTON CORE

Class A

- SW Expressway (I-95 South).

- Third Harbor Crossing and approaches in South Boston -- as part of a through bypass system.

- Upgrading of Southeast Expressway as part of through bypass system.

- Basic line-haul program (transit, busway, other).

  - Mainline

  - Needham

  - Midlands

  - Other

<u>Class B</u>

- Improved or new arterials in sections of the Southwest and Inner Belt alignments.

- Third Harbor Crossing -- to connect Mass. Pike and Southeast Expressway to the airport -- as bypass to Central Artery.

- Improvements to existing commuter rail services.

- Circumferential transit system.

<u>Class C</u>

- Land development in I-95 Inner Belt and Southwest Expressway corridors; as part of "no build" option -- road treatment for land access only.

- Washington Street Elevated and alternatives.

- Green Line extensions in Roxbury-Mattapan.

- Coverage transit proposals in inner communities.

- Central Artery improvements.

- Central subway improvements.

<u>NORTHWEST</u>

<u>Class A</u>

- Western Connector -- from Route 2 at Alewife to Mass. Pike.
- Red Line extension to Alewife.
- Use of Fitchburg Division corridor of B&M.
    - Commuter rail
    - Rapid transit extension of Green Line
    - Shuttle service
    - Busway
- Grand Junction Truck Road.

Class B

- Circumferential transit in Cambridge and Somerville.
- Arterial extension of Route 2.
- Fitchburg Division of B&M -- rapid transit or busway.

Class C

- Coverage transit proposals in Cambridge and Somerville.
- Traffic Operations program on Alewife and Mystic River Parkways.

C. REGIONAL TRANSPORTATION SERVICE ALTERNATIVES

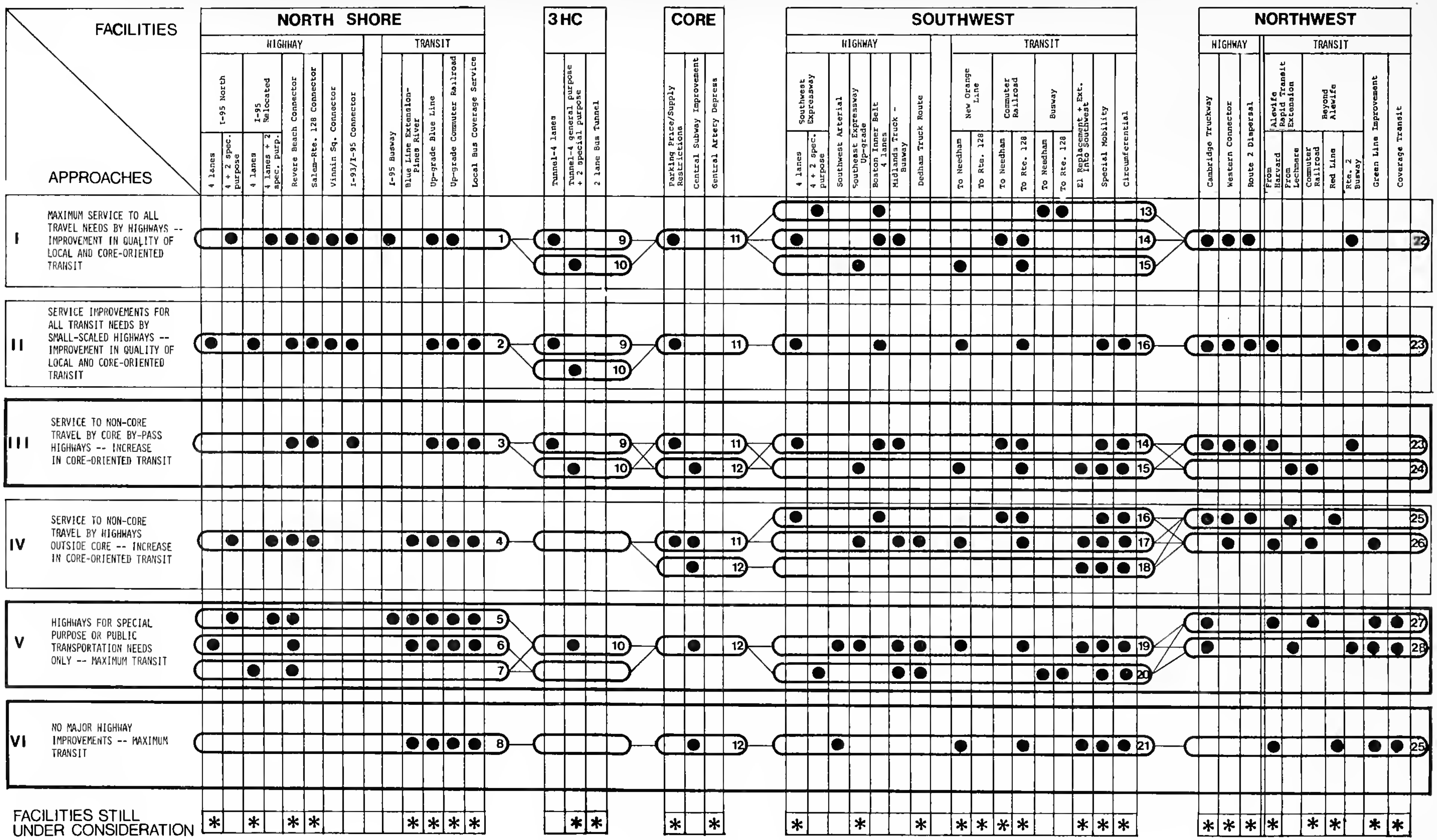
One of the criticisms voiced often by many of the participants has been that BTPR is focusing its efforts on facility planning without a regional framework or transport service approach as to the role of transportation in the region. The attached chart, developed jointly by BTPR staff and several members of the working committee, attempts to interrelate the various major transportation facilities under consideration to alternative regional transportation service philosophies.

The chart indicates two important factors:

- That one regional transport service approach can be achieved in several ways through different combinations of the facilities under consideration.

ALTERNATIVE TRANSPORTATION SERVICE IMPROVEMENT APPROACHES

FIG. 11



- A given facility is consistent with several transport service approach. For example, building the Third Harbor Tunnel is consistent with four of the six transportation service alternatives.

The following paragraphs briefly describe the major features of each transportation service alternative.

Alternative 1

This approach would emphasize maximum improvements to the expressway system consistent with evolving policy (non-core service). This would mean construction of the through bypass system of I-95 North, I-95 Relocated, the Third Harbor Crossing, the Boston Inner Belt and the S outhwest Expressway, plus other improvements such as the Route 2 Mass. Pike connection and special purpose roadways in the B&M right-of-way on the Fitchburg Division. This approach has the following features:

- Taking maximum advantage of Interstate 90-10 money to make as many transportation improvements through interstate highway projects within the limits established by the evolving policy.
- Reliance on busway solutions where other transit options are foreclosed-through the construction of highway facilities (this affects the Penn Central Mainline and Fitchburg Division primarily which would be converted to busways under this approach).
- Keeping existing line-haul rail transit service (commuter or rapid transit), but providing major improvements or extensions only when it is determined that there is a market for such improvements after the highway facility is operating.

Alternative 2

This approach involves construction of a through bypass system of expressways, but at a scale reduced from Approach 1 (four lane expressways as opposed to six -- as a result, busways would not be featured). Existing

line-haul transit services would be maintained with some new investment. This approach would feature:

- Completion of a smaller scale (four lane) expressway system of I-95 North, I-95 Relocated, Third Harbor, Boston Inner Belt, and the Southwest Expressway (a variant on this expressway program would include using an upgraded Southeast Expressway instead of constructing a new Southwest Expressway and/or using the Northeast Expressway rather than I-95 Relocated.

- Some improvements in line-haul transit with whatever investments are consistent with the proposed expressways. These would include:

  - providing rail service in Southwest Corridor and in Needham Branch as the basic plan;

  - maintaining commuter service on the Midlands as an interim or permanent measure;

  - development of whatever long-term rapid transit extensions that are consistent with or make sense in light of the expressway program and limits on resources.

<u>Alternative 3</u>

In this approach, the regional expressway program would include only those facilities that provide a limited bypass system around the core. This would consist of the Third Harbor Crossing as the key improvement, with a connection to existing facilities in the North, and to the Mass. Pike and the Southeast Expressway in the South (and perhaps I-93). The Southwest Expressway and I-95 North would not be constructed as through facilities, but might be constructed for local arterial service (not as part of a regional through system). Connector roads and spurs would be constructed in outlying areas, and tied into Route 128, which might receive Interstate designation and selectively upgraded under this approach. In this approach, a major emphasis and priority would be put on making substantial improvements in the line-haul transit system, (either commuter rail or rapid transit -- whatever makes the best sense in each of the corridors).

Alternative 4

This approach is the converse of Approach 3. The regional expressway program would include only those facilities that provide new capacity in the outlying portions of the region where necessary or desirable. The facilities providing a bypass around the core of the region would not be included. Thus, the Third Harbor Crossing would not be included in the program, but some appropriately scaled facility could be considered in the North Shore and Southwest corridors as part of a program of improvements to provide better subregional and local movement, perhaps as spurs on the interstate system with appropriate connections to the arterial system for dispersal. Emphasis would be on major improvements to the line-haul transit system consistent with highway construction.

This approach would feature:

- A major cutback in a commitment to build a through bypass system with the resultant chance that Interstate highway funds may not be available for transportation system improvements within Route 128.
- A heavier commitment to line-haul transit improvements to provide service to the core.

Alternative 5

This approach assumes that the major investments will be for public transportation. The optimum public transit program would be developed for each subregion. Major highway facilities would be constructed only if they can fit into or help out the particular public transportation program or to provide whatever local road improvements are deemed desirable by the localities themselves.

This approach would feature:

- A major commitment to develop a high level of capital resources and operating subsidies to finance a major upgrading

of the existing public transportation system and provision of new services.

- Commitment to the best possible package of transit improvements in each corridor and subregion (both line-haul and coverage) with a time-phase strategy for implementation -- short-term improvements maximizing use of existing facilities; long-term improvements with major capital investments -- extensions to transit lines -- rebuilding of existing facilities where necessary; new experimental programs to try out different technologies, etc.

- Major new highway construction (non-local) only to help out the transit program; e.g.:

  - bus service on Route 1 to feed transit service on B&M in the North Shore (busway maybe);

  - Revere connector to feed transit stations'

  - new ramps off Route 128 to serve transit stations at appropriate locations.

Alternative 6

This approach assumes that the only major investments will be for public transportation, and within this, for those facilities that do not require the construction of any new highways anywhere within Route 128. Under this approach, no more expressways would be built, and a major program would be initiated to upgrade and extend not only the existing public transportation system, but also to provide a wide variety of new and different public transportation services that can handle new and emerging travel requirements. This approach would have essentially the same public transportation improvements as in alternative 5, but there would be no major highway improvements.

D. CODING THE BASE TRANSPORT NETWORK

The base highway network for the Boston Region has been prepared. This section provides documentation of the network and the coding procedures and conventions that were incorporated in its development.

Node Coordinates

Card Column	Data Item	Description
11-15	node number	node identification
31-40	X coordinate	in hundredths of feet
41-50	Y coordinate	in hundredths of feet

Links

Card Column	Data Item	Description
1	card number	2 for all link data cards
2,3	jurisdiction	geographic index of link. See attached maps.
4,5	link type	00: centroid connector 01: local street capacity <600 vph 02: minor arterial $600 \leq$ capacity <1200 vph 03: major arterial, $1200 \leq$ capacity 04: limited access expressway 05-13: reserved for proposed alternative links 14: toll links 15: dummy links and ramps

For one-way streets, there are certain changes in link types.

01: local street, capacity <1200 vph
02: minor arterial, $1200 \leq$ capacity <2400 vph
03: major arterial, $2400 \leq$ vph capacity

Card Column	Data Item	Description
7-10	A node number	link identification
12-15	B node number	link identification
19-22	distance	hundredths of miles (for toll links, this field contains the toll in dollars)
24	T/S	T: time data follows (artificial links) S: speed data follows
26-29	time/speed	zero volume time or speed (A to B)
30-33	time/speed	off-peak time or speed (A to B)
34-37	time/speed	peak period time or speed (A to B)

Card Column	Data Item	Description
38	direction	1: one-way link 2: two-way link
39	T/S	T: time data follows S: speed data follows
41-44	time/speed	zero volume time or speed (B to A)
45-48	time/speed	off-peak time or speed (B to A)
49-52	time/speed	peak period time or speed (B to A)
59,60	capacity indicator	index of volume/capacity/speed relationships
61-66	capacity	maximum capacity of link at service level E

General Description

The network overlays the EMRPP region. The links represent only the existing highway system and committed projects.

The network is considerably abbreviated in the area outside Route 128. For the most part, only numbered routes in that area are coded. Inside Route 128, enough detail is included to replicate arterial traffic flow. That is, local circulation will flow through the network without being forced onto the arterial links inappropriately. In the CBD, a great amount of detail was necessary to fulfill this objective.

The main functions of this network are to represent the "status quo" highway option, and to provide the starting point from which to code alternative networks generated by the BTPR. Both the "status quo" and the alternative networks ultimately were used in forecasting and evaluating future traffic flows associated with alternative transportation systems.

Network Data Sources

- Coordinate data: Most of the coordinate data was excerpted directly from a 1963 highway network prepared by Peat, Marwick and Mitchell and Co., under contract to the Massachusetts Department of Public Works. (This coordinate data will allow the use of a Calcomp Plotter to display the network.)

- Link data: The PMM & Co. network was also the source of most of the new link data. This data was reduced considerably in order to eliminate unnecessary network detail, and in order to conform with the new BTPR zone system. Data from the Mass. Dept. of Public Works supplemented this.

Using the plots that show only travel to and from selected areas, it is possible to get an idea of the proportions between local and through traffic, and the connectivity of given areas with other areas.

For each plot, a computer printout showing travel volumes assigned to each link has been prepared. In addition, there are regional summaries of vehicle miles and vehicle hours of travel.

VI. PROCEDURES FOR TRIP GENERATION AND DISTRIBUTION

BTPR trip tables, representing zone to zone travel were developed for assignment to BTPR networks. Tables were developed for each of the two extreme networks. Tables were developed for each of the two extreme land use alternatives.

For use in Phases II and III, sets of zone to zone trip tables for assignment to BTPR Networks were developed which meet the following criteria.

- They recognize revised forecasts of population, car ownership and employment distributions. These forecasts are based on extrapolations of trends occurring in the decade 1960-1970.
- They make use of the most recent trip generation analysis done with the 1963 home interview survey data...that is, the analysis done for Task A.
- They are as "facility-neutral""as possible. An assumption was Made that transportation service levels would be about the same in 1980 (the future analysis year) as they are today. This implies investment in transportation only to maintain existing service levels. Completely new or vastly improved or degraded facilities are not assumed.

Because they are based on the 1963 survey data, there is no basically new information on trip making behavior included in the revised trip tables. Such new information will be available from the U.S. Census Bureau in its tabulation of 1970 journey-to-work data.

The procedure to develop the trip tables is based on the Fratar technique. This involves increasing or decreasing travel between pairs of zones, depending on whether population, car ownership and employment increased or decreased in each zone. Trips were examined as they were produced or attracted by each zone. Growth factors for the forecast period (1963-1980) were calculated from population, car ownership and employment data for trip production and attractions. Each of these items is weighted where morethan one contribute to a given trip generation or attraction. Weights are based on statistical analysis of the 1963 survey data. Trips were disaggregated and factored by purpose before being aggregated and split by mode.

Several products result from this procedure. Zone-to-zone trip tables for all purposes together split by mode are the primary product. These were assigned to highway and transit networks. An intermediate product is sets of zone-to-zone trip tables by purpose. These are useful for examining changes in the different major components of urban travel (e.g. the journey-to-work). In addition, tables of zone-to-zone automobile and truck travel are produced.

Trip purposes defined for this exercise are: 1) work; 2) shopping; personal business and social-recreation (three purposes combined); 3) school; 4) non-home based (for any purpose); 5) truck; and 6) external trips (from and/or to areas outside the region). Strictly speaking, non-home based and truck and external trips are not purposes, but they can be handled statistically like purposes, and must be included because they significantly contribute to total travel demand.

Calculations for the growth factors used to adjust the zone-to-zone trips are shown on the next page.

Coefficients are those developed in the Task A work done by Peat, Marwick, Mitchell and Company, for 894 zones. They are applied to the BTPR 529-zone system. Differences between the two zone systems are in aggregations of zones in the outerpart of the region. Within Route 128, the two zone systems are virtually identical. The majority of zones (about 80%) in the BTPR system are inside Route 128.

Population and employment data were forecast by the BTPR prior to the trip table adjustments. Documentation for this work is contained in other memos. Car ownership and disaggregation of total employment into the categories manufacturing and other (Mfg.Oth) and retail, services and finance, insurance and real estate (RSCFIR) was done as part of the trip table adjustments. Automobile ownership was assumed to vary with population and income, according to the following general sets of relationships:

- high income communities autos = .40 (Pop.)
- average income communities autos = .37 (Pop.)
- low income communities autos = .35 (Pop.)

Figures for high and average income communities were lowered somewhat where accessibility by public transportation is high. Data for the region shows car ownership per person rising from .29 to 1963 to .38 in 1980.

The proportions by community that existed between Mfg.Oth and RSCFIR in 1963 were assumed to exist also in 1980. This is the basis for disaggregating employment as required for adjusting the trip tables for 1980. For Downtown Boston, only retail employment is required. The 1980 figure of 36,000 retail employees is based on a special study of Downtown Employment done by the BTPR (documented in BTPR Memo, "Downtown Employment Forecasts", File B.3.11, dated 10/5/71).

The results of the procedure described thus far are shown in tabular form as follows:

REGIONAL TOTALS OF PERSON TRIPS BY PURPOSE
(Walking, School Bus and Taxi Trips not Included)

Purpose	No. Trips in 1963 (Surveyed)	Regnl. Growth Factor	Trends Extend. No. Trips in 1980 (BTPR)	No. Trips in 1980 Interpolted from Task A	1980 Task A / BTPR
Work	1,882,202	1.35	2,540,435	2,235,531	.88
Soc.-Rec. Shopping & Pers. Business	3,074,312	1.41	4,319,617	4,700,484	1.09
School	354,963	1.14	405,380	545,141	1.34
Non-Home Based	1,446,505	1.32	1,915,590	1,794,377	.94
Total	6,757,982	1.36	9,181,022	9,275,533	1.01

TRIP PRODUCTIONS

Trip Purpose	Zone Type	Growth Factor
Work	All Zones	1980 pop./1963 pop.
Shopping, Personal	CBD & Urban Zones	1980 pop./1963 pop.
Business & Social-Recreation	Suburban & Rural Zones	1980 cars/1963 cars
School	All Zones	1980 pop./1963 pop.
Non-Home Based	CBD	$.354\left(\frac{'80MFGOTH}{'63MFGOTH}\right)+.605\left(\frac{'80RSCFIR}{'63RSCFIR}\right)+.187\left(\frac{'80pop.}{'63pop.}\right)$
	Urban	.249 " +.748 " +.139 "
	Suburban	.343 " +1.789 " +.151 "
	Rural	.317 " +2.288 " +.154 "

TRIP ATTRACTIONS

Trip Purpose	Zone Type	Growth Factor
Work	All Zones	1980 emply./1963 emply.
Shopping, Personal	CBD	$4.228\left(\frac{'80\ Retail}{'63\ Retail}\right) + .442\left(\frac{'80\ pop.}{'63\ pop.}\right)$
Business & Social-Recreation	Urban	$1.238\left(\frac{'80RSCFIR}{'63RSCFIR}\right) + .319$ "
	Suburban	4.706 " + .344 "
	Rural	7.356 " + .321 "
School	All Zones	1980 emply./1963 emply.
Non-Home Based	CBD	$.354\left(\frac{'80MFGOTH}{'63MFGOTH}\right)+.605\left(\frac{'80RSCFIR}{'63RSCFIR}\right)+.187\left(\frac{'80pop.}{'63pop.}\right)$
	Urban	.249 " +.748 " +.139 "
	Suburban	.343 " +1.789 " +.151 "
	Rural	.317 " +2.288 " +.154 "

External trips were estimated for 1980 by scaling back 1990 Task A forecasts for such travel. Light and heavy truck trips were factored separately to 1980. The trip generation information developed in Task A was again used. The same factors were used for zonal productions and attractions as follows:

Trip Purposes	Zone Type	Growth Factor					
Light Trucks	All Zones	.0969	$(\frac{'80MFGOTH}{'63MFGOTH})$	+.0673	$(\frac{'80RSCFIR}{'63RSCFIR})$	+.1130	$(\frac{'80pop}{'63pop})$
Heavy Trucks	All Zones	.1182	"	+.0276	"	+.0574	"

It is desirable to carry along separate estimates for heavy trucks because planning facilities for them is an important issue in the Planning Review.

All trips by purpose were then summed to produce a 1980 total person trip table. These trips were then split by mode based on 1963 zone-to-zone modal split proportions. Transit persons and auto persons are the result of this step. Because the ratio automobiles/total person trips was directly used to estimate 1980 auto trips, auto occupancy is implicitly assumed to remain the same. Here again, the assumption of maintaining existing service levels enters the calculations. An adjustment was made for major new facilities that exist now, but did not exist in 1963 (.e.g, the Quincy Red Line extension, the Mass. Turnpike extension and Interstate 93). Adjustments were made directly to the transit persons and automobile modal split percentages by zone pairs. Adjustments were based on recent vehicle and passenger counts and consideration of competing modes.

One further major adjustment was made to introduce data collected in a special origin-destination survey done in June 1970 at Logan Airport. After all calculations and adjustments outlined above were made, 1980 trips to and from the airport zone were substituted into the overall

transit person and highway vehicle trip tables. 1980 trips to and from the airport were estimated using the Fratar technique, and factors and procedures as described in this memo for all other zones. They were calculated and introduced at the end of the process so they would not be subject to the final adjustments made to recognize the new facilities built between 1963 and 1970. An explicit auto occupancy factor of 1.9 was used to estimate airport auto trips.

The overall procedure outlined here requires only initial estimates of population and employment (two categories) and auto ownership, as well as the existing trip tables. A different set of trip tables can be produced given different distributions of population, employment and auto ownership. It is the intention of the Planning Review to produce at least one other set of trip tables. These would reflect a distribution of population, employment and auto ownership based on a recognition of desirable policies to aid in improving social and economic development and to improve the physical environment. As a general feature the trip tables based on these themes for improvement would be characterized by more trips to the downtown area, a greater proportion of these trips by public transportation, and a shorter average trip length for the region. Furthermore, creating more intense activity nodes in suburban areas should shorten average trip lengths in these areas.

It is intended that these alternate trip tables be assigned to the networks being tested in Phases II and III. This will give an idea of the adequacy of alternative transportation facilities under assumptions of urban growth which differ from a simple extrapolation of current trends and policies.

VII. PROCEDURES FOR MODE SPLIT ANALYSIS AND FORECASTING

After examining and rejecting the cross-elasticity model for forecasting modal choice at the zonal level, another, more traditional model was adapted for BTPR use.

This section describes the theory and structure of the techniques developed in the BTPR to forecast choice of mode. These techniques were applied in the Southwest corridor travel demand studies in order to simulate the consequences of several alternatives in facilitiy construction and downtown parking oost. These same methods were used again in the Northwest Corridor studies. The model can be used either as a corridor or regionwide model.

A. THEORY

The BTPR mode choice model estimates the probable rate of choice of transit for a trip, given an array of the characteristics of the competing transit and auto services and given the level of auto availability at the trip origin.

The model in abstract can be represented as a two-stage process. First, for a given origin-destination pair, the door-to-door "total trip cost" is evaluated for each mode as the sum of the various resources of time and money expended in order to make the trip, weighted by the behavioral values (in terms of dollar value) of each type of resource. that is, for the given trip, for each mode:

$$(1) \quad COST = K_1X_1 + K_2X_2 + \ldots + K_nX_n$$

where the X_1 are among such items as walking time, waiting time, in-vehicle time, or out-of-pocket cost (ie., tolls or fares), and where the K_1 are the dollar transportation system "marketplace". In turn, these total costs for each mode and the auto availability at the trip origin determine the mode split to transit as a probabilistic function:

$$(2) \quad \emptyset(COST_{transit,} COST_{auto,} ZCARS_{origin})$$

The variable ($ZCARS_{origin}$) in the function may be seen as an "elaboration" of the perceived value of the total auto cost. The perceived worth of auto cost is evaluated by the traveler in respect to his ease in obtaining the use of an automobile.

METHOD

In the Southwest Corridor studies, the model was implemented in three-district sets of mode split response surfaces -- one for each of three trip "purposes" defined as follows:

home-based work -- a trip that is to or from the traveler's home from or to his job;

home-based "other" -- a trip that is to or from the traveler's home from or to anywhere other than his job;

non-home-based -- a trip that is neither to nor from the traveler's home.

For the two home-based purposes, per capita rate of car ownership at the trip origin was chosen to represent the ZCARS variable. For the non-home-based trip model, the mode split of home-based trips attracted to the origin of the non-home-based trip was substituted for ZCARS.

Variables (X_i) and their respective values (K_i) that were selected for use in the total cost functions are shown in Table 1A for transit and Table 1B for auto.

The dollar values of the various categories of travel time listed in Tables 1A and 1B are similar to those reported by many, including the following: Thomas E. Lisco, "The Value of Commuters' Travel Time -- A Study in Urban Transportation", University of Chicago, 1967; Thomas C. Thomas, "Value of Time for Commuting Motorists," Highway Research Record 11.0 24S Washington, D.C. 1968; Thomas C. Thomas, "The Value of Time for Passenger Cars: An Experimental Study of Commuters' Values", Stanford Research

Institute, Menlo Park, California, 1967.[1]

C. MODEL DEVELOPMENT

1963 system data as listed in Tables 1A and 1B were taken and modified from the data base prepared for the BTPR tests of the Charles River Associates' Direct Demand Model.[2]

These system data and their values were then used to evaluate the transit and auto total cost functions in 1963 for each origin-destination interchange. Each system variable was taken as an average of the peak and off-peak characteristics weighted by the distribution of traffic between the peak and off-peak periods.

1963 auto ownership and trip interchange data were taken from the 1963 Dwelling Unit Survey.[3]

A computer program was written to stratify the 1963 trip data into average mode split points in cells constructed at arbitrary intervals in each dimension of the independent variables (that is, $COST_{transit}$, $COST_{auto}$, and ZCARS) in the Ø function.

Also, Martin J. Fertal, Edward Weiner, Arthur J. Balek, Ali F. Sevin, "Modal Split", Office of Highway Planning, Federal Highway Administration, U.S. Department of Transportation, December, 1966; Salvatore J. Bellomo, Christopher G. Turner, Denis K. Johnston, "A Mode Choice Model for Relating Demand to Investment", Alan M. Voorhees and Associates, Inc., a paper presented at the fifty-first annual meeting of the Highway Research Board, Washington, D.C., September, 1971; "A System Sensitive Approach for Forecasting Urbanized Area Travel Demands", technical memoranda numbers 2, 3, and 5, Alan M. Voorhees Associates for the Federal Highway Administration, U.S. Department of Transportation, February,,1971; "Technical Report No. Two -- Travel Forecasting", Alan M. Voorhees and Associates, a report to the Twin Cities Area Metropolitan Transit Commission.

[2] BTPR Memo B.0.5.2 ("CRA Direct Demand Model", J. MacMann, 5/26/72).

[3] Wilbur Smith and Associates, for the Eastern Massachusetts Planning Project; Boston, Mass.

These points were interpreted as average values of the dependent variable (mode split) as an implicit function in the independent variables at their observed average values within the intervals.

Two additional programs were written: one to "rectify" these stratified points by linear interpolation into a standardized lattice of points -- points that occur at uniform values in each of the independent variables (that is, all values of Ø would occur at defined values of $COST_{transit}$, $COST_{auto}$, and ZCARS); the second to apply the rectified lattice to compute the 1963 trips by mode as a function of the 1963 cost and ZCARS data, in order to test and evaluate the structure and specification of several variants of the model.

An example cross-section of the final response surfaces is shown in Figure 1.

D. MODEL APPLICATION

A set of computer programs was developed to apply the mode split model to estimate and display the different traffic consequences in 1980 of several of the BTPR alternative proposals for transit and highway service.

A diagram of the overall process of applying the model is given in Figure 2. The following step-by-step description is keyed to that diagram.

- Estimate 1980 total trips by purpose (Fratar Model). The product of this step is a set of matrices by purpose describing the combined total (transit plus auto) 1980 person trips among the 529 traffic zones in the BTPR region. This step is documented in detail in previous BTPR memoranda.[4]

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[4] BTPR Memo B.3.6, "Traffic Forecasting Methods", J. MacMann, 1/10/72; and BTPR Memo B.3.6, "Creation of Trip Tables for Phase II Analysis", Brian Barber, 1/11/72.

- Prepare coded networks -- Build and Skim Trees. "Networks" are the source of transportation system data used in evaluating the total cost functions. The method of their coding is reported in another BTPR memo by J. MacMann on 1/3/72.

  The output of this step, "skim trees", is (computer-processible) matrix summaries of the highway and transit networks that describe the characteristic times and costs by each mode (as in Table 1A and 1B), attributed to each possible origin-destination movement in the BTPR region -- under each alternative being tested.

- Estimate 1980 cars per person. Car ownership rates are estimated from existing trends, and held constant among all the alternatives.[5]

- Calculate 1980 home-based mode splits. Evaluate the total cost functions for each mode for each origin-destination pair and interpolate from the mode split lattice the corresponding mode split.

- Calculate 1980 home-based trips by mode. Using the origin-destination mode splits from Step 4, allocate each of the two home-based Fratar total trip tables into trips by mode. Summarize the mode splits of trips attracted to each zone for input to the non-home-based trip model.

- Calculate 1980 non-home-based splits and trips. As in Steps 4 and 5 above, using mode split of attracted home-based trips for ZCARS.

- Load and report networks. Assign traffic by mode onto minimum time paths in the networks. Report and summarize link volumes.

- Summarize trips. SE6 has prepared computer listings that summarize in a common format the traffic by mode under each of the various alternatives. For each alternative and for each mode, the following tables are available by purpose separately and totaled across all three purposes:

  529-zone productions and attractions
  89-district productions and attractions
  89-district trip interchange volumes
  21-district productions and attractions
  21-district trip interchange volumes

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[5] Ibid., Brian Barber

E. RESULTS

Table 2A contains summary descriptions of the Southwest Corridor Alternatives tested with the BTPR mode split model. A summary of the summaries of the corresponding forecast 1980 traffic by mode is reported in Tables 2B and 2C.

F. LIMITS AND ASSUMPTIONS

There are certain caveats worth bearing in mind when interpreting the results of the BTPR traffic forecasting model reported herein. There is an intrinsic structural error in this BTPR forecasting model: the total of person trips by both modes between each origin-destination pair is fixed in respect to the service characteristics of the transportation system. (The mode split sub-model described herein merely divides this fixed total traffic between the modes.) This and some of its consequences are discussed at length in another BTPR memorandum.[6]

Nevertheless, there is nothing to suggest the introduction of bias in the method by which the BTPR's 1980 mode splits themselves were estimated. The biases of the total trip volumes will thus permeate the mode split process as follows:

- Among origin-destination pairs where transportation service is improved over 1963 -- interchanges affected by construction of either transit or highway facilities -- both transit and auto volumes are likely to be underestimated.
- In alternatives representing transportation service inferior in comparison to that of 1963 -- in alternatives in increased auto parking cost -- volumes by both modes are overestimated in the affected interchanges.
- Whenever any interchanges are not affected explicitly by either the construction of new facilities or the imposition of auto parking cost penalties, their forecast trip volumes by each mode are likely to be somewhat inflated.

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[8]Op.cit. J. MacMann, BTPR, 1/10/72

Table 1A

VARIABLES AND VALUES IN TRANSIT TOTAL COST FUNCTION

Variable	Value (In Cents)	Description
Walk time	10.43/minute	Any walking time to or from station or stop or transferring enroute.
Wait time	10.43/minute	Time spent waiting to board transit vehicle(s).
In-vehicle time	4.17/minute	Time aboard any transit vehicle(s) and in private car access in the case of park-ride trips.
Auto access penalty	104.3/trip	A margin to represent the perceived cost of forgoing the use of one's car during the time it is parked at the transit station (the car might otherwise be used by self or family).
Fare	--	Any and all transit fare required.
Auto access costs	--	Auto operation cost for park-ride and kiss-ride. Also parking lot fee for park-ride.

Table 1B

VARIABLES AND VALUES IN AUTO TOTAL COST FUNCTIONS

Variable	Value (In Cents)	Explanation
Walk time	10.43/minute	Time to walk to car at origin and from car at destination.
Park time	4.17/minute	Time spent driving around looking for parking space at destination.
Line time	4.17/minute	Driving time enroute from origin to destination,
Operating cost	3.107/mile	Marginal cost of operating vehicle for trip (gas, oil), divided by car occupancy.
Tolls	--	Divided by car occupancy.
Parking fees	--	One-half the rate at origin plus one-half the rate at destination, divided by car occupancy.

TAble 2A

DESCRIPTION OF MODE SPLIT ALTERNATIVES

Alternatives are described by a two-character code: the first character, a number, reflects the configuration of transport facilities; the second character, a letter, represents the level of Downtown Boston parking costs.

Facility Alternative I:	No new facilities.
Alternative II:	Rapid transit to Route 128 in Needham with appropriate park-ride and feeder bus, connecting to relocated Orange Line; Green Line service to Franklin Park; improved frequency of railroad to Canton. No new highways.
Alternative III:	Rapid transit branches to Route 128 in Needham and Canton connecting with relocated Orange Line; Green Line to Mattapan Square; Red Line from Fields Corner to Readville via Mattapan Square; high speed trolley from Fields Corner to Mattapan Square, Red Line Quincy branch local south of Columbia; inner circumferential rapid transit, South Station to community college via Dudley, Kenmore, and Central Squares. No new highways.
Alternative IV:	Transit as in Alternative II. Four-lane I-95S with restricted access north of Forest Hills, connecting to Central Artery at Massachusetts Avenue. Third Harbor Crossing connecting to I-95N through to Route 128N.

Parking Cost Alternative A:	1972 parking cost rates.
B:	1972 parking cost rates, factored by 1.67 for work purpose only.
C:	1972 parking cost rates factored by 2.67 for work purpose only.

Table 2B

DOWNTOWN BOSTON
PERSON TRIP ENDS (1,000's)

Transit:	Work	Other	NHB	Total
1963	210	95	42	347
IA	285	101	44	430
IB	313	101	44	468
IC	342	101	44	487
IIA	293	105	45	442
IIIA	301	107	46	453
IIIB	329	107	46	482
IIIC	358	107	46	511
IVA	291	104	45	440
Auto:				
1963	139	107	118	363
IA	210	128	137	476
IB	182	128	137	448
IC	153	128	137	419
IIA	202	124	136	463
IIIA	194	122	135	452
IIIB	166	122	135	424
IIIC	137	122	135	395
IVA	204	125	136	466

"Downtown Boston" is defined as that portion of the peninsula [illegible]

Table 2C

SOUTHWEST CORRIDOR
PERSON TRIP ENDS (1,000's)

Transit:	Work	Other	NHB	Total
1963	148	82	23	253
IA	145	58	24	227
IIA	151	61	25	237
IIIA	175	76	30	281
IVA	149	60	24	234
Auto:				
1963	363	346	266	1176
IA	554	825	338	1717
IIA	547	822	337	1706
IIIA	524	807	332	1663
IVA	549	823	337	1709

The area defined as the "Southwest Corridor" in this table is shown in Figure 3.

FIGURE 11

CROSS-SECTIONS OF HOME-BASED WORK MODE SPLIT SURFACE AT ZCARS = 0.35 CARS/CAPITA

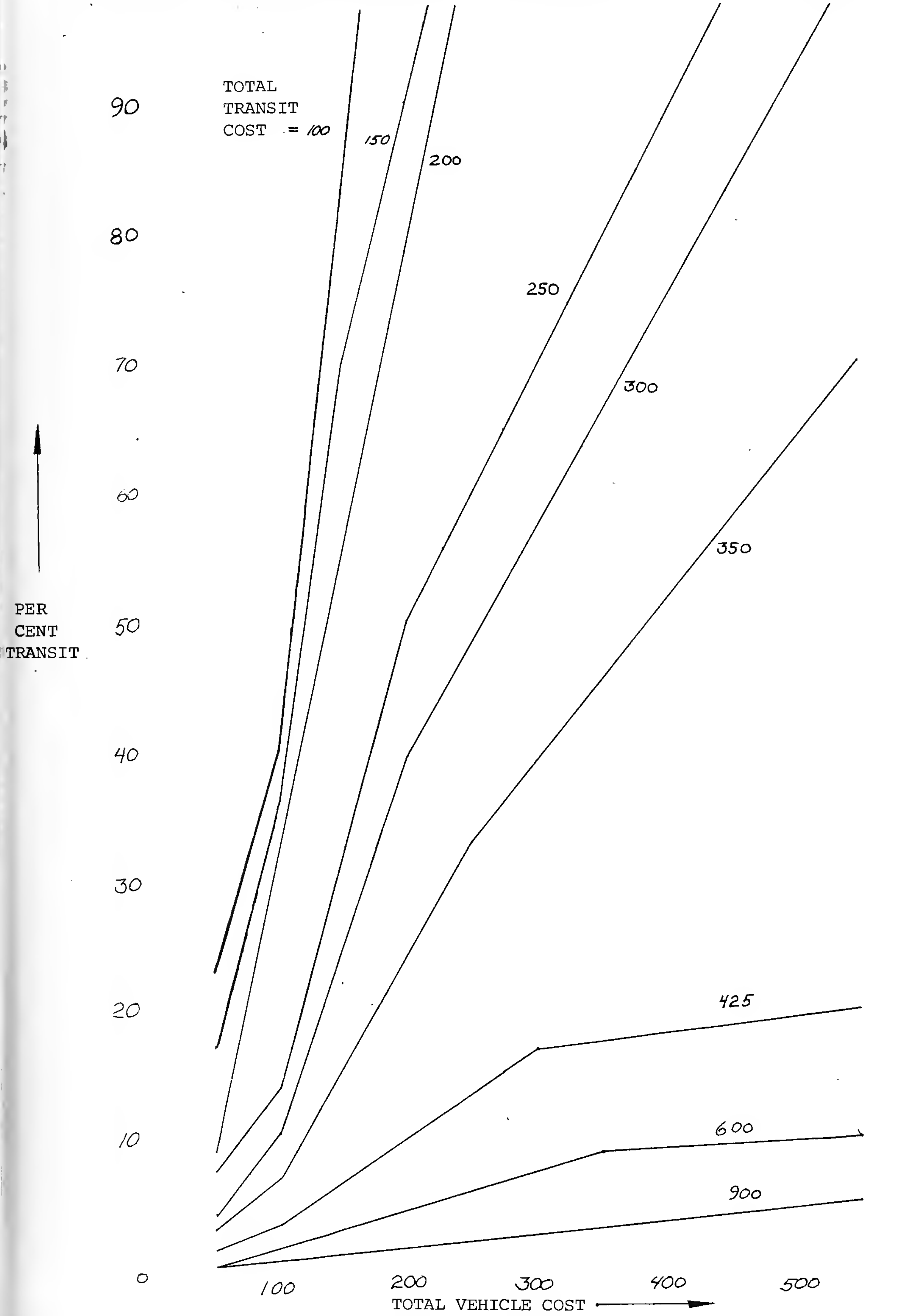
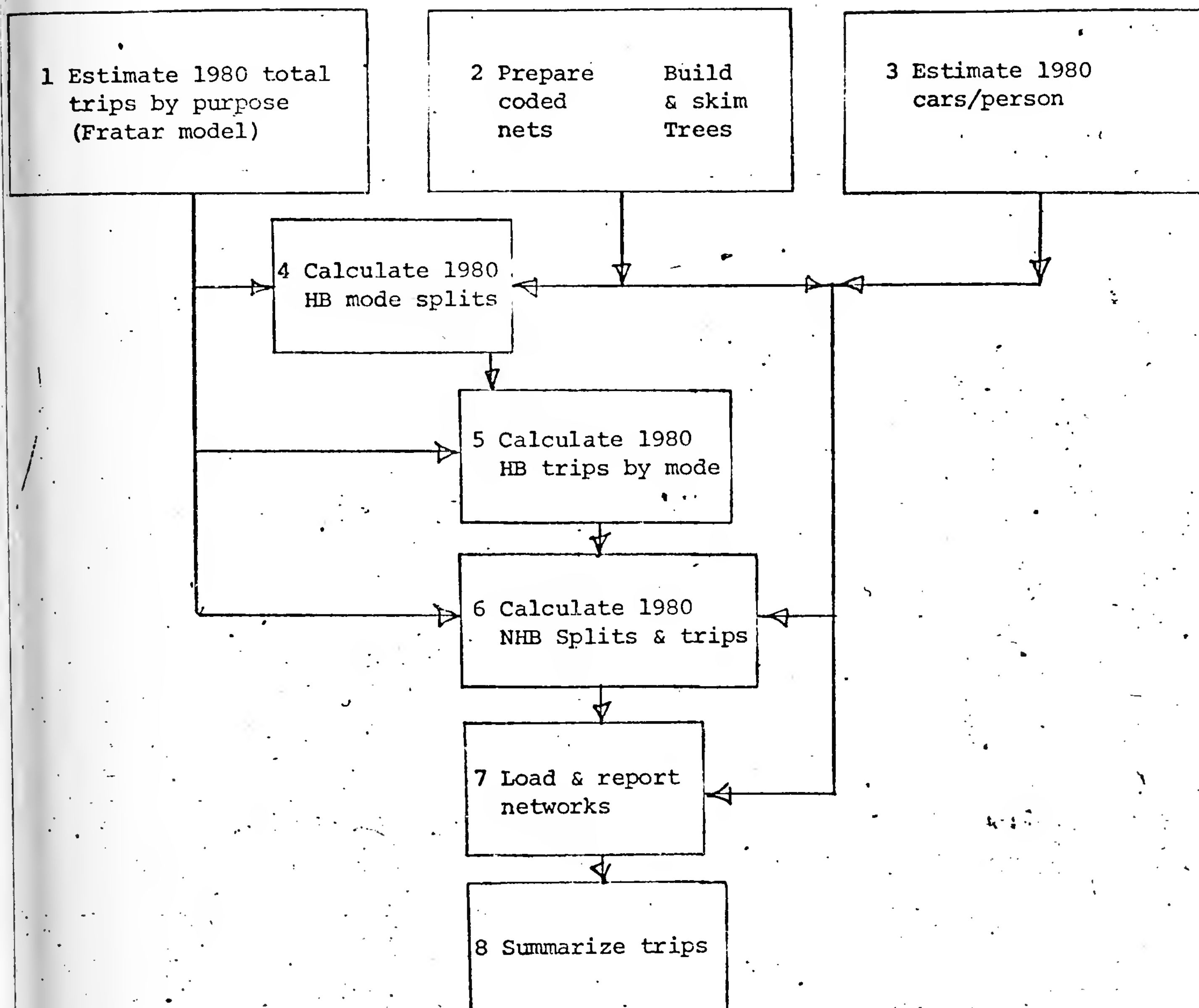


FIGURE 12

MODE SPLIT PROCESS



VIII. PROCEDURES FOR NETWORK ASSIGNMENT

Network Assignment

An all or nothing minimum path procedure was used for both highway and transit assignments. Network assignment was a very often performed job in the BTPR since so many proposals were tested. This meant an economical procedure was required. Networks were developed for the 529 zone region. TASK A network provided the basis for BTPR networks. BTPR networks were coded in standard format for input to the Alan M. Voorhes and Associates, Inc. TRIPS assignment programs.

Highway assignments provide information on directional link vehicle loadings and turning movements as well as summaries by sixteen geographic jurisdictions and sixteen link classes of vehicle miles of travel, vehicle hours of travel, and average vehicle speed. Assignments were prepared separately for trucks and automobiles.

Transit assignments provide data on station boardings and exits, as well as summaries of person miles and person hours of travel and average speed. Both transit and highway assignment procedures required interzonal trip tables and network descriptions as inputs.

Adjustments to all assignments were made by hand. Adjustments were based on capacity diversions, especially during peak periods, as well as the existence of competing facilities (within each mode) which had travel times and costs only slightly higher than the computer assigned paths. In some cases (i.e. the Sumner-Callahan Tunnels), special studies were conducted to determine the extent of peak hour congestion.

The highway networks were calibrated before computer assignment with the latest estimated volume information. All assignments were for an average 24-hour weekday. A total of about 70 complete regional network assignments were prepared.

IX. CROSS ELASTICITY MODEL INVESTIGATIONS

A. INTRODUCTION AND BACKGROUND

This section reports on the investigations, findings and use to date of the cross-elasticity travel forecasting model by the BTPR. Conclusions on its possible further use by BTPR are also presented. Reference is made to several reports and documents in order to avoid duplication.

The basic reference document for the model is the 1967 report of Charles River Associates, A Model of Urban Passenger Travel Demand in the San Francisco Metropolitan Area. This 1967 report describes the estimation of the cross-elasticity model using 1963 Boston region data for 97 districts.

The reason for BTPR using or attempting to use the cross-elasticity model in the first place are contained in the November, 1970, Study Design for the BTPR (Study Element 6: "Land Use and Travel Forecasting", pp. 6-16 to 6-20). The reasons cited there for use of the model by BTPR are its policy senstivity and its ease of use compared with conventional multi-step travel forecasting techniques. That is, the model forecasts amount and distribution of travel in a way that is sensitive to a wide range of alternatives being tested by BTPR, (as contrasted with a relative lack of policy sensitivity of conventional forecasting methods). Also, the model is a direct demand formulation. It forecasts travel between limited numbers of origin-destination pairs directly, rather than in several steps for all zones and interzonal pairs in the region.

The Study Design report also states: "The primary disadvantage of the model is its relatively untested nature" (p.6-20). Therefore, the BTPR early in its existence developed a work program to investigate in more detail how the cross-elasticity model should be used in the Planning Review. This work program ("Work Program for Use of Cross-Elasticity Model/Dodotrans in Phases I and II of the Restudy" Daniel Brand, September 15, 1971) outlined an initial set of mathematical/ theoretical investigations of the model for Phase I of the BTPR. If these were successfully concluded, full scale accuracy and sensitivity tests would be undertaken with the model using base date (1963) data and computer programs written for the purpose. The work program also outlined possible Phase II BTPR use of the model, providing it performed satisfactorily on all preceding tests.

The early mathematical/theoretical investigations of the model are documented in the report, "Analysis and Appraisal of the Cross-Elasticity Model for Use in the BTPR, Phase II", Daniel Brand, January 1, 1972. This report described how the model is mathematically independent of zone size and how to factor to forecast peak hour travel. More importantly, the report contains calculations and analysis of the transit and auto work equations. The analyses indicated probable nonsensical behavior of the model if incomes and car ownership are allowed to vary from base date (1963) values used in model estimation. Otherwise, promising behavior was anticipated with respect to appropriate senstivity to, and forecasting ability for changes in all other variables in the model, partiuularly the important transportation system variables. It was therefore decided to go ahead with the next step of the work program, namely full scale 1963 base bata implementation of the model to produce trip tables. BTPR staff member Jeff MacMann has carried out this work during the last several months.

This report documents the major findings of the 1963 system test. As such, it updates and supplements the working memorandum of Jeff MacMann, "CRA Direct Demand Model", dated May 26, 1972.

The 1963 system test with the model documented here resulted in a better understanding of the several options for further use of the model by BTPR. Two of these options have already been exercised. These are (1) manual calculations using the elasticities at their mean to predict induced travel on a new facility for selected O-D parts; and (2) using the aggregate regional output of the BTPR assignment programs to estimate induced travel on a facility improvement, relative to its null or no-build case. The first option has been described and exercised for several I-95 North alternatives, and for the Third Harbor Crossing (memos by Daniel Brand, April 10, 1972; and Brian Barber, June 7, 1972, respectively). The second option has been described and exercised for a Southwest Expressway (I-95 South) alternative (memo by Daniel Brand, July 20, 1972).

It is expected that as the results of the 1963 system test with the cross-elasticity become better known, these and other options for use of the model will be exercised by the BTPR and its successors. This memo ends with an elaboration of the possible options for using the existing estimated cross-elasticity models, and recommendations as to their possible use by BTPR.

B. 1963 SYSTEM TEST

The major purpose of the 1963 system test of the cross-elasticity model was to produce synthetic trip tables with the work trip equations of the model for both transit and auto and observe their behavior and reasonableness, particularly as compared with (observed) trip tables from the 1963 EMRPP Home Interview Survey.

1. Data Inputs

The region was partitioned into 529 zones for the test, as contrasted with the 97 districts for which the model was originally estimated. The 529 zones are the same BTPR zones being used for the 1980 Fratared highway trip tables and assignments. It was recognized at the outset that a test at this level of dis-aggregation was an extreme one. That is, the model which was estimated using trip data for 97 zones (or approximately 104 interchanges) was being required to produce information for over 25 times as many interchanges.

At least three factors mitigate the extremeness or difficulty of the test, however. The first is that one result of a finer zone system, which is to increase the range of values of socio-economic data describing the zones, did not happen here. The socio-economic data coded for each of the fine zones were the values holding for the larger (97) zones on which model was estimated. The second mitigating factor was that the models are designed to be theoretically insensitive to zone size, or numbers of zones, insofar as mathematics can provide for such insensitivity. That is, the variables whose values vary with zone size or numbers of zones are linear/homogeneous with respect to these factors. For example, in the auto work equation:

$$N = (\alpha x + \beta \ln x) \prod Y^{\gamma_k}$$

the variables which vary with zone size are the Y variables. There are two of these (k=2), one at the origin (Employed labor force) and one at the destination (Employment share). Each of these has an exponent (or γ coefficient) of one, and thus, the effect of the variable on N is linear with zone size (as measured by itself). Also, as the number of zones increases, the number of interchanges (S) will vary as the square of the number of zones. To keep a constant regional total number of trips, each interzonal interchange (N) should decrease at the same rate as the number of interchanges (S^2) increases. Since $Y^{\gamma k}$ varies inversely

with S^2, the appropriate behavior results (e.g., double the number of zones and S doubles, S^2 quadruples and Y is one-fourth its previous value).

The third mitigating factor is that the coding conventions for inputing system data to the model were carefully designed to minimize wide fluctuations in the data. This was done not so much because the system test was at such a high level of disaggregation, but because the numbers of trips produced (predicted) by the cross-elasticity model is extremely sensitive to changes in values of the system variables. System variables are included not only for the subject mode (e.g., highway times and costs for highway trips), but also for the competing or substitutable mode as well (e.g., transit times and costs). Since cross-elasticities are (generally) positive, inordinately high system values for competing mode variables would have the effect of increasing subject mode trips nonsensically if great care is not taken in the manner in which such system variables are coded. The coding conventions are described in detail in the document, "Coding Conventions, Instructions and Data Ranges for Use in the 1963 Test of the Cross-Elasticity Model - BTPR" (Daniel Brand, January 5, 1972). All system variables input to the 1963 test were carefully coded in accordance with the instructions in that document.

One factor persists, however, in making the 529-zone test somewhat more difficult than a 97-zone test. At the same time, this factor also makes the test somewhat better than just a goodness of fit test on the data set used for calibration. The factor is that the test data set, even though for the same year and the same region used for model estimation, is composed of a different combination of system times and costs and traveler socio-economic descriptors than the data set used for estimation. Thus, one might argue* that the coefficient estimating technique (quadratic programming) which minimized errors for the 97 zones calibration data set may not have arrived at the same coefficients by minimizing errors for the 529 zone test data set. However, a behavioral model useful for BTPR purposes should have coefficients well-grounded in travel behavior cause and effect, not in the vagaries of the compositions of particular data sets. Thus, to the extent that the data set for this test varies from the data set used for model estimation, the 1963 system test can be considered a useful and productive test of the ability

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* As did Steven Glazier in "The Technics and Politics of the Boston Transportation Planning Review", Draft S.M. Thesis, MIT, June 1972, p.52.

of the cross-elasticity model to describe and predict future travel in the BTPR region.**

2. Results

The overall results of the test in terms of goodness of fit were disappointing as far as indicating immediate usefulness of the model to produce wholly synthetic trip tables for the BTPR.

Several aggregate measures of fit, comparing estimated (predicted) 1963 work purpose trips by mode with observed work trips by mode from the 1963 Home Interview Survey were calculated. For transit work trips, the ratio of total observed over total estimated trips is .603 or a 65% overprediction. For auto work trips, the corresponding ratio is .319 or a 214% overprediction(!)

For trip ends attracted into the CBD, (Mass. Avenue up the peninsula), the picture is somewhat brighter. The corresponding ratio ($\frac{\text{obs.}}{\text{est.}}$) for transit work trips is .794 or a 26% overprediction. For highway work trips, the ratio is 1.185 or a 15% underprediction. This suggests that the model might be used with appropriate factoring to estimate trips to the CBD. Transit work trips to the CBD comprise nearly 60% of the observed 1963 transit work trips in the region. The percent is no doubt higher now. However, only 13 percent of total highway work trips were to the CBD. This percent is decreasing over time. Thus, no reasonable highway link volumes could be gleaned from assignments made with CBD-oriented trip tables (even on links approaching the CBD). However, transit link volumes (particularly on the radial rapid transit links) might be reasonably estimated using only CBD-oriented work trips. In 1963, nearly 60% (again) of total transit trips to the CBD (all purposes) were work purpose trips. Of course, before such procedures can be considered viable options for the BTPR, additional examination of the test results is necessary.

Table 1 contains the multiple correlation coefficients (R^2) between the observed and estimated trip volumes at six levels of aggregation (three different numbers of zones, times two travel "dimensions"). R^2 represents the ratio of total variation (variance) in the observed variable that is explained by the model. As

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** However, to the extent that BTPR could use travel forecasts made for fewer zones (e.g., say 200), the test could be unproductively severe and could result in abandoning an otherwise usable and useful technique.

TABLE 1 R^2 COMPARISONS BETWEEN PREDICTED AND OBSERVED TRIPS

Transit Work Trips	Trip Interchange	Attractions
529 Zones	.14*	.72
89 Districts	.71	.93
15 Superdistricts	--	.99
Highway Work Trips		
529 Zones	.18*	.73
89 Districts	.31	.57
15 Superdistricts	--	.99

Notes: 1. Simple correlation coefficients (r) are the square root of these values (e.g., 0.72 = 0.85

2. Zero values of trips are excluded from the table (R^2 with zero trips interchanges raise these values by .01 to .04)

* The observed trips are themselves small sample data. The average number of interviews in each area used in the calculation is less than (1)!

such, it is more meaningful than the often referred to simple correlation coefficient (r) between observed and estimated values of trips. R^2 is generally taken as equal to the square of r. Thus, for these fractional values (always), R^2 is always smaller than r for values of R^2 other than 0 or 1.

The entries in Table 1 become more meaningful as levels of aggregation become higher (fewer zones; and trip ends rather than trip interchanges). This is in part because R^2 is intended to represent the proportion the model is explaining of some presumably known quantity. At high levels of disaggregation (trip interchanges between 529 zones) the observed numbers of trips are hardly (!) known with certainty. In fact, the total number of interviews in the 1963 Home Interview Survey is roughly equal to the number of trip interchanges at the 529 zone level. When the interviews are separated by mode, the observed "data" becomes even less "certain". Thus, it is a real question at very disaggregated levels whether the surveyed trips or the modelled trips are the "truth". The asterisked entries in the table should probably be considered meaningless and ignored.

The values of R^2 in the table for trip end data are quite comparable to R^2's, usually obtained with conventional trip attraction equations. Also, as expected, the R^2 values in the table generally improve as the level of aggregation improves. However, the fact that this improvement for highway work trips is not consistent is cause for concern and further investigation.

Finally, it can be noted that link volumes are generally used in transportation planning, not the volumes on which the R^2 calculations in Table 1 have been made. Links represent a level of aggregation somewhere between trip interchanges and trip ends for 89 districts. However, since no assignments with the estimated 1963 trips were made, the reader can only speculate using the information in the table, as to what the resulting R^2 might have been.

Aggregate measures of goodness of fit of trip tables are only one measure of the worth of the model to BTPR. In order to understand why the model produced the above results, two further sets of analyses were undertaken. The first involved disaggregation of information at both the zone and variable levels by printing out all the input data and calculations of trips by mode (the so-called "x arrays") between fourteen zones (196 interchanges). The 14 zones were selected on the basis of criteria which provided for zones representing a wide range of: income,

car ownership rate, employment density, trip length, transit service, size of zonal population, homogeneity vs. heterogeneity of the zone, and relative and absolute size of residuals (difference between observed and estimated volumes). Examination of the x arrays allowed a number of findings to be made. First, the computer input data and computations were individually checked and found to be accurate. That is (importantly) the programs were found to be working correctly. Second, the contributions of changes in each independent (S/E and system) variable to changes in estimated trips could be checked at real values for individual zonal pairs over and above the checks for "typical" zones made in the January 1, 1972, Phase I memo referred to above. These contributions were found to be reasonable and quite consistent with the model's elasticities of demand. The contributions of changes in variables from their base (or average) values is important in a policy testing model. The size of the contribution of an absolute value of income some other variable is no cause for concern. The constant term in most of the cross-elasticity model equations makes the largest or second largest single contribution to the estimated trip volume.

The most important finding from the x array analyses was a better understanding of the negative number prediction problem with the highway work trip equation. This behavior and the subsequent truncation to zero of all such "negative" interzonal trips appears to explain why the highway work trips equation "fit" as badly as it did (as described above). The "negative trip prediction" problem is described in the next section under "discussion of results".

The second set of further analyses was an examination of residuals for the highway work trip equation. Residuals are the errors or differences between observed and predicted trip values. These were related to (correlated with) values of several independent variables. The independent variables were income, car ownership and employment density. A high correlation between size of error and size of variable would imply a systematic bias in the prediction. For example, if variation in income explains a high proportion of the error, then trips will be overpredicted systematically from high income areas (if the simple correlation is positive). If the simple correlation is negative, there will be systematic underprediction. The results for R^2 were as follows:

Income	0.17
Car Ownership	0.13
Employment Density	0.02

The simple correlations were all positive (R^2 is always positive).

It is quite difficult to interpret these R^2's. On the one hand, a 17 percent explanation of the error with income does not appear significant. On the other hand, combined with all the other bad behavior of the auto work equation, it is one more reason why the equation shouldn't be used as it stands to synthesize highway work trips. It is also possible that the R^2's are associated with the negative trip prediction problem. Possibly also, the higher income and car ownership rates in the lower density suburbs are associated with higher trips rates and thus higher absolute errors (heteroscedasticity). The exact cause remains unknown and inconsequential until such time as similar tests are run with an auto work equation re-estimated to eliminate the negative number problem (discussed below).

3. Discussion of Results (Findings)

There appears to be one principle reason for the overprediction by the model of the highway work trips, and one principle reason for overprediction of transit work trips. The highway trip problem relates to the particular form of the model used, which is capable of, indeed did, produce negative trips. The transit trip problem is the problem of the model "seeing" the whole region as having the good transit service of the generally CBD-oriented sample of zonal interchange used for model estimation. Aside from these principle problems, there is a short list of lesser reasons to which the errors appear to be ascribable. The entire set of findings add up to lessons to be learned as to what to do in further model estimation work. More importantly, and immediately for BTPR, the findings mean the elimination of certain options for using the model as it is presently estimated, and also the continued availability of other options. All options are discussed in the next section. This section discusses the results of the model tests with 1963 data.

The Negative Number Problem (Highway Work Trips)

The negative number problem with highway work trips arises from the particular log/linear form of the highway work model which was estimated:

$$\frac{N}{Y} = \alpha x + \beta \ln X$$

where: $\frac{N}{Y}$ is the dependent variable

N is the number of trips

Y is certain socio-economic variables

α ,B are coefficients

X is system variables and remaining S/E variables

The coefficients α and β can be both plus and minus (minus on the costs by the subject mode, plus on the cost by the substitutable mode). Thus, the right hand side of the equation can be negative. Since Y is always non-negative, N, the number of trips predicted, will be negative in such cases. This appears to have happened in many cases. Whether the finer (529) zone system used for the system test aggravated the problem is difficult to tell.

The method of correcting for the negative numbers of estimated trips in the test was at the same time simple, appropriate for the test, and disastrous. The negative numbers were simply truncated to zero, leaving only the positive side of the distribution of estimates of the random variable, N, the number of trips. There was no compensating subtraction from the positive estimates of N when the negative estimates were all "added to" in effect, to produce zero (non-negative) estimates. The compensating subtractions (which would lower the total estimated travel and thus improve the aggregate fit), could be done by creating a pool or reservoir equal to the sum of the "added to's", and then subtracting the reservoir from the positive trip estimates in proportion, for example, to their size. This is not a recommended procedure. It is presented only to illustrate that the summary measures of fit of the highway work trip equation show an overprediction which includes the total reservoir of "added to's" resulting from the truncating procedure. Whether the overprediction equals the size of the reservoir is not known. The fact that the model predicted well for trips to the CBD, where there would be few negative values, indicates that it might. However, the negative numbers of trips were not summed in the test. If the overprediction did essentially equal the size of the reservoir, the equation at least produces estimates accurate at the mean (unbiased) but which have a wide variance. This is perhaps to be expected, given that the equation was estimated at 97 zones and forecast at 529 zones, and given the variance of the Home Interview Survey Data itself at that level of disaggregation. In any event, the highway work equation, in its present form, is very badly behaved and unusable to BTPR to predict auto trips directly.

The negative number problem can be completely avoided by using the product form model used for transit work trips:

$$N = X^{\alpha} e^{\beta X}$$

In this equation, the negative numbers (i.e., some of the coefficients) are all kept in the exponents. They work to produce fractional values of N, not negative values. Fractional values of N will often occur, and appropriately so in a predictive travel model for widely separated zones. However, negative values are completely avoided.

There are at least two other additional reasons why a product form model is recommended for any future estimation of the cross-elasticity model. The first is that the multiplicative model implies that the variables act jointly (not separately) in explaining travel behavior. This would appear to be logical, (e.g., higher income groups are less sensitive to travel price changes, and more sensitive to travel time changes, than lower income groups). The second reason is that the elasticities of demand with respect to system variables using linear (e.g., highway work) demand equations retain the values of N/Y, the dependent variable, in them. Product form equations do not. Use of elasticities to estimate induced travel with the present highway work equation remains a viable option for BTPR as discussed later. However, the presence of N/Y in the equation for the elasticity, η;

$$\eta_x = \frac{\alpha x + \beta}{N/Y}$$

requires assuming a (e.g., mean) value for N/Y in order to avoid computing N/Y with the equation for every zonal pair, travel between which is affected by a system change. Avoiding the computation of travel $(\frac{N}{Y})$ using the whole demand equation is generally the reason why elasticities are used in sensitivity analyses in the first place. The implications of assuming the regional mean value of N/Y in computing η are documented in the memo "Calculating Induced Highway Travel Using BTPR Assignment Program Output", July 20, 1972, by Dan Brand. The implications of the assumption net out to underestimates (i.e., conservative) estimates of induced travel due (only) to the assumption. These underestimates are compensated for elsewhere in the procedure as described in that memo.

It is important to clarify any possible confusion about biasing the highway work elasticities as estimated in the model because of the model overprediction. The

elasticities (really, the coefficients) were estimated in the model using 1963 input data. Nowhere are the "overpredicted" output data (strictly speaking, probably due to the truncation procedure used in the "overprediction") from the model used in the calculations of the elasticities. Thus, there are no errors in the computed elasticities with the model due to overpredicted output data.

The Sample Selection Problem (Transit Work Trips)

The principle reason for the transit work trip overprediction appears to be the method of selecting the sample zonal pairs used for transit model estimation. Zonal pairs were selected for which there were at least three or six transit interviews from the Home Interview Survey. The larger number was for the outlying zones in the region for which a 7 percent sample was collected in the survey. The smaller number was for the 3 percent sample area. The net effect was to produce a transit sample which consisted entirely of zones interchanging 100 or more (expanded) trips from the survey as a condition for including "only those zonal pairs for which transit travel represents a reasonable alternative to auto travel, a condition for obtaining a meaningful measure of modal cross-elasticities.*

There are two important consequences of this sample selection procedure. Only one was recognized at the time of model estimation. This was that "it largely limits the data base to downtown-oriented trips, because most transit trips to go downtown".** This limits the range of values of the variables over which the model was estimated. However, it also biases the model with respect to variables not included in the model. For example, transit travel time reliability and convenience are increasingly recognized as important (but difficult to measure) determinants of the use of grade separated rail rapid transit lines to the CBD. If such variables are not explicitly in the model, the model "sees" the entire region's transit service as having the reliability and convenience of the CBD-oriented rail rapid transit which makes up the sample used in model estimation. This would be less of a problem in terms of biasing the model output if the transit sample were drawn randomly from around the region. However, this was not the case! The result is the overprediction of non-CBD-oriented transit trips results relative to CBD-oriented trips as described in the previous section.

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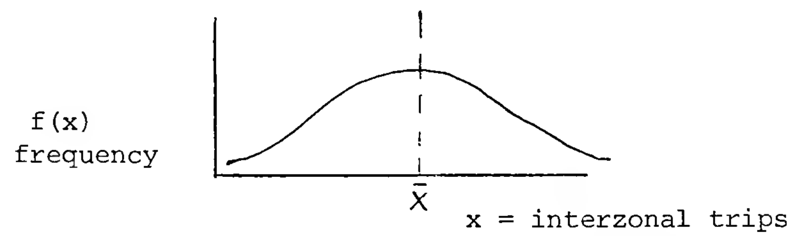
* CRA report of 1967, op. cit., p.51.

** Ibid., p. 51. (75.3% of 1963 transit trips were included in the sample.)

Sample Bias (Transit and Highway Work Trips)

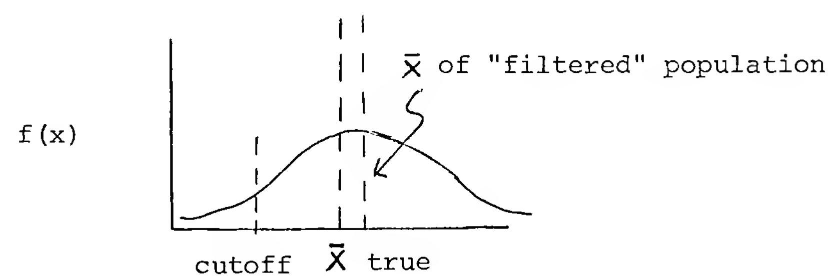
The second consequence of the sample selection procedure affects both the highway and transit work equations. However, the transit results are likely to be more seriously affected. The problem, apparently unrecognized during model estimation, is that selecting zonal transfers having more than (e.g.) N interviews biases upward, the tripmaking which the model "sees" being made under a given set of conditions. The problem is aggravated for zonal pairs averaging few or fractional numbers of transfers (trips). This may be seen from the fact that the number of trips between a zonal pair sampled by the Home Interview Survey is distributed as a random variable. The general case is illustrated as follows:

General Case of Random Variable x



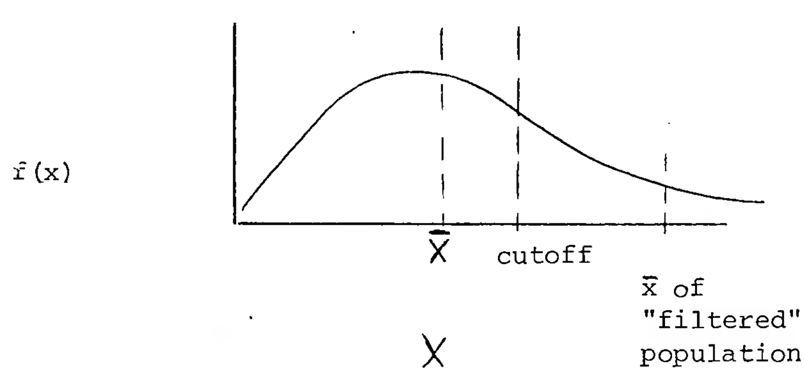
For zonal pairs exchanging large numbers of trips, a three or seven interview cutoff will only eliminate a few zonal pairs. This biases the mean of the remaining ("filtered") population of trips only slightly, and can be illustrated as follows:

Large Interchange Volume Case



However, for zonal pairs exchanging small numbers of trips, a three or seven interview cutoff eliminates most zonal pairs. Thus, the mean number of interzonal trips remaining in the sample is, relatively speaking, greatly exaggerated.

Small Interchange Volume Case



The result of the cutoff procedure in sample selection is that the model (in its estimation) was exposed to higher tripmaking for a given set of conditions than actually occurred. The model naturally carries this result forward in prediction, continuing to overpredict travel under certain travel conditions. This would tend to happen most for travel to "intermediate" areas. That is, travel to the CBD will tend to be unbiased, because of the large (in terms of attractions) zones (again, the model "fit" trips to the CBD relatively well for both modes). Widely scattered zones will tend to contribute few biased data points, because few (but not all) will fail the cutoff. The 97 zone estimation produced 97^2 or about 10,000 possible zonal pairs. The 1963 Home Interview Survey produced about 30,000 usable interviews. Thus, the average was about 3 interviews per zonal pair for both modes combined. Note the similarity to the cutoff number for most of the region.

Sample selection criteria for any future model estimation which have as their objective insuring that certain supply side conditions are present (e.g., transit service is available) should generally be based <u>on</u> those supply side conditions. Demand side indices, particularly ones calculated using small sample data, should be avoided.

<u>Other</u>

Only one more reason can be advanced at this time to the above list of reasons for lack of fit of highway and transit work trip models. This is the usual problem of different data sets for model estimation and test. That is, even though the data purport to measure the same variables at the same year, such data are inevitably coded somewhat differently by different people at different dates. It is felt that this problem, though present in this test, has been minimal. Many of the personnel who coded the test data in 1972 coded the estimation data in 1966. In addition, the coding conventions and data ranges described in the memo noted previously were carefully designed to be consistent with the earlier coding conventions and data ranges with one exception. This exception was in the case of transit system coding which eliminated access mode paradoxes in a simple and direct way. This was essential, since the direct demand model permits no such sloppiness in coding. The estimation data unfortunately suffered from some of the access paradoxes.

However, the test results reported above contain no discernible evidence that indicates that the difference in data sets used for estimation and test contributed significantly to the lack of fit with the model.

C. OPTIONS FOR BTPR USE OF THE CROSS-ELASTICITY MODEL

1. List of Options

There are several ways in which the cross-elasticity model could conceivably be used by an agency like the BTPR in travel simulation and prediction. These will first be quickly listed here. These "options" will then be discussed in terms immediately relevant to BTPR, in the next section in view of the findings of the system test reported above, and the earlier BTPR Phase I feasibility study documented in an earlier report. Finally, conclusions on recommended options for BTPR use of the model are given in the last section. The list of options follows:

1. Using the full models as estimated for highway and transit to predict travel directly (i.e., produce wholly synthetic trip tables). This would involve producing new demand curves (with the present estimated model) as distributions and levels of the full set of socio-economic variables (land uses) change.

2. Same as 1, holding only income and car ownership constant at 1963 levels.

3. Same as 2, predicting travel only to the CBD for work purposes and factoring to 24-hour, all purpose trips.

4. Predict induced new interzonal travel on transportation improvements. This involves predicting shifts along demand curves with fixed 1963 slopes. One way to do this would be to use calculated elasticities of demand to predict the changes in travel between every zonal pair affected by a transit improvement. The increases in travel would be calculated and summed by computer.

5. Predict induced travel on a new facility manually using elasticities and selected zonal pairs affected by a transit improvement. This is the option already exercised for North Shore and Third Tunnel alternatives, as documented in previously mentioned reports.

6. Predict induced travel on a new facility using elasticities and the regional (VMT and VHT) output of BTPR assignment programs. This is the option already exercised for a SW Expressway alternative as documented in a previously mentioned report.

2. Discussion of Options

The first option should be discarded as a result of the BTPR Phase I "paper" study of the model reported on in the above mentioned January 1, 1972, memo by this writer. The combined elasticity of demand with respect to the affluence variables, (income and car ownership) appears to have the wrong sign in the presently estimated models for purposes of (short run) travel demand forecasting as

per Option 1. To its credit, the cross-elasticity model appears to have captured an aspect of travel behavior heretofore unnoted in travel forecasting models. That is, since it is the first direct demand model, it shows for the first time empirically that travel occurs when conditions at the destination are more valuable (to the traveller) than conditions at the origin. This involves a subtraction. Since the model was supplied with affluence variables to measure conditions at the origin, the model simply made its own subtraction, by putting a minus sign in front of the affluence variables. This correct (to this writer) but as yet unconfirmed capturing of travel behavior results in unusable elasticities of demand with respect to the affluence variables for immediate BTPR policy testing purposes with the presently estimated model. The problem is documented elsewhere.* Further estimation of these models should use a formulation such as the following:

$$\text{Affluence}^{\alpha_1} \left(\text{Conditions at}_j^{\alpha_2} - \text{Conditions at}_i^{\alpha_3}\right)^{\alpha_4}$$

Option 2 is not a viable option for the BTPR because the findings reported upon in the previous section of this memo do not warrant use of the models as presently estimated to forecast travel directly to all destinations.

Option 3 is a viable option for predicting transit travel on major radial transit links, but not for predicting highway travel. As noted previously, transit work trips to the CBD (Mass Avenue up the Peninsula) comprise nearly 60% of total observed 1963 transit travel to the CBD. The percent is no doubt higher now. In turn, a high proportion of trips on the radial rail transit lines are destined to the CBD. An even higher proportion of CBD-oriented transit trips would use the proposed rail extensions and express bus services being considered by BTPR.

Option 3 would involve the use of (conservative) factoring based on 1963 data to (1) correct the CBD transit travel forecasts by the fitting error reported previously (0.794); (2) convert from work to all purpose trips by corridor; and (3) to convert from CBD destined trips to all destinations for each rapid transit line. Such factors are easily obtained.

Option 4 is a viable option, conceptually. However, it would involve the writing of fairly complicated new computer programs to implement the method. The output of selected link analysis would be input to the new programs to determine all zonal pairs affected by the new or improved links. The percent changes in system

* "[illegible] Method in Land Use and Travel Forecasting", Daniel Brand. [illegible] Reprint, [illegible]

characteristics for each affected zonal pair (at the zonal level) would be multiplied by the appropriate elasticities of demand, and the resulting induced travel summed over all zonal pairs and assigned to each selected link. The elasticities could even be recomputed for each zonal pair if such computations are indicated by the formulae (as for the auto work equation). Needless to say, Option 4 is a reasonably formidable exercise, probably surpassing Options 1 and 2 in incremental effort to BTPR (and certainly also in payoff).

Option 5, a manual method, is also a viable option for BTPR, having been exercised already for North Shore and Third Tunnel alternatives as noted above. However, the method is crude and has disadvantages of an ad hoc method which attempts to patch together some existing data to produce some hopefully useful estimates. This should become clearer with discussion. The method has been exercised in two variations.

The first North Shore application started by using selected link output to determine which groups of zonal pairs contributed what proportion of the fixed 1980 travel (volume assigned) to a base "no build" major representative link in the corridor. A hopefully representative sample of about 15 groups of zonal pairs were selected which contributed large volumes to the link. These interchanges would presumably be significantly affected by a major improvement in the corridor. The percent change in travel conditions was computed for each of five North Shore alternatives for each selected zonal pair from skimmed trees "before and after" the alternative. The percent induced change in travel for each selected zonal pair was computed using the percent change in travel conditions and the appropriate elasticities. Finally, the percent change in travel on the alternative at a screenline across the original (selected) link was set equal to the weighted average percent increase in travel. The weights were the relative contributions of travel from each sample zonal pair to the <u>original</u> selected link from the original base assignment.

This, of course, is an approximate method of prediction. The major approximations unique to this application of Option 5 are the incomplete and non-randomly selected set of zonal pairs contributing travel and the fact that the selected link output uses the original set of minimum time paths from the original no improvement assignment.

With regard to the first approximation, it was felt that the limited number of zonal pairs which could be manipulated manually should be picked non-randomly with refer-

ence to how much travel they would contribute to a new facility. The second approximation is the troublesome one. That is, only zonal pairs selected on the basis of the existing no build distribution of travel on a link across a screenline are used to calculate user cost savings and the resulting induced travel. The user cost savings of travelers newly diverted to the new facility tend to be omitted from the calculation. The assumption is implicitly in the application that the user cost savings of newly diverted travelers is percentagewise equal to the savings of travelers between the existing selected zonal pairs. This is not a terrifying assumption in this approximate method under most circumstances. However, when an alternative improvement is in a different location from the original (selected) link, as happened with the Lynn Woods I-95 alignment being in a different location than the existing and proposed Route 1 links, the assumption can lead to misleading results. That is, existing Route 1 travel tended not to be benefitted as much by a Lynn Woods alignment as by a substantial Route 1 improvement, but a whole set of other zonal pairs not in the original selected sample of interzonal pairs were benefitted (percentagewise) more by the new highway on the new alignment. The method showed the Lynn Woods alternative not being quite as attractive in terms of perceived travel benefits (of course, to the original groups of Route 1 travelers) as the major Route 1 improvement (B). In reality, Lynn Woods travel benefits were probably underestimated, showing the approximations inherent in this method when the original selected link is either on a different alignment, or is otherwise not very representative of the facilities making up a proposed transit improvement.

The second application of Option 5, the Third Harbor Tunnel calculation of induced travel, divided the entire BTPR region into 12 large districts. On the basis of a selected link assignment <u>with</u> the new facility, the (entire) portions of the region were delineated between which travel would be affected by the new tunnel. For each affected interdistrict pair, the no build travel times (line haul costs were assumed not to change), and the fixed (Fratared) 1980 auto trips were listed. A four or five minute time savings was assumed to accrue with the new tunnel to <u>all</u> travelers between the affected O-D pairs, regardless of whether all travel between the O-D pairs used the new tunnel.

The percent which this four or five minute time savings was of the no build time was computed, and was used (with the appropriate elasticities) to compute induced travel not in percent terms but in absolute travel volume between each part of the region. The induced intersubregional volumes were then summed between all affected O-D pairs to produce induced travel due to the new tunnel.

This appears to overstate the amount of induced travel. The computation of the absolute levels of induced travel should be done at the facility level, where it is known how much volume is directly affected by the improvement, not at the interzonal pair level where it must be assumed that the total time savings from the new facility accrue to all travelers, regardless of how small a fraction use the new facility. Ideally, the second application of Option 5 should have weighted the percent improvements in travel time by the contributions of the intersubregional pairs to travel on the selected link (the new third tunnel). Lacking this, the weighting of percents might have been by total interzonal volume. The latter would only be (partly) justified for truly regional facilities. The final weighted average percent would be multiplied by the appropriate elasticities to obtain the percent induced travel on the new facility. This percent would then be converted into induced volume on the link using the assigned volume on the link.

Contrasting the two applications of Option 5, the first application worked with percents from a limited number of zonal pairs, while the second method worked with sums of changes in O-D volumes for the entire affected portions of the region. Also, the first application used changes in minimum path time <u>and</u> distances (to compute line haul costs) for each alternative, whereas the second assumed a 4 or 5 minute time (only) saving for all travel affected in whole or in part by the proposed tunnel improvement.

There are lessons to be learned from each application of the option! Selected link output should be used from the assignment <u>with</u> the new facility if it is available. This means, of course, as many selected link assignments as facility tests, instead of one selected link assignment to a no build network. Skimmed tree travel times <u>and</u> distances (to compute costs) should be obtained from networks with and without the improvement. Percent changes in travel costs and induced travel should be maintained right down to the link level. Only then, should absolute amounts of induced travel be computed. If the facility to be tested is truly a regional facility (such as the Third Harbor Tunnel or the entire Southwest Expressway, but probably not the North Shore or Northwest alternatives) the entire region can be divided into a few zones such as in the second application. These would be selected on the basis of a selected link assignment <u>with</u> the proposed facility, if such a selected link assignment were available. With these guidelines, Option 5 appears to be a viable option for BTPR.

Option 6 is a viable option for BTPR. It has already been described and exercised for a SW Expressway alternative in a separate memo. It appears to be a conceptually elegant method whose assumptions can be explicitly and tightly specified. These assumptions, and their probable (compensating) biases, are detailed in the separate memo.

The most important assumption inherent in Option 6 involves the use of non-equilibrium travel times and costs. However, that assumption is inherent in all current BTPR traffic forecasting work. None of the 6 options for the use of the cross-elasticity model by BTPR would likely be an exception. Option 6 probably helps best to understand the biases and errors introduced by the use of non-equilibrium travel times and costs for travel prediction. Beyond this, Option 6 has the distinct advantage of being implemented (given the readily available output from the assignment programs) by a set of trivial computations.

3. Conclusions on Options for BTPR

The recommended options for further use of the cross-elasticity model by BTPR are number 3 for transit only, and 5 and 6 for both transit and highway. There may be some question for Options 5 and 6 as to whether the appropriate output is readily available from existing BTPR transit assignment programs. This, of course, should be taken into consideration. Decisions as to expending resources to apply any of these options are beyond the scope of this memo. This memo (only) concludes that on the basis of the investigations and use of the cross elasticity model to date, Options 3, 5 and 6 as described in the first sentence remain viable and relatively implementable ways to improve BTPR travel forecasts.

Options 5 and 6 (the most easily and already implemented options) might also both be exercised for a similar highway alternative as a further check on their accuracy. For transit testing, it should be noted that the transit work trip equation does not include any auto variables. In effect, the model states that changes in auto service (e.g. line haul speed increases due to new expressway construction) do not produce any measureable changes in transit travel. Whether or not this is an accurate representation of reality can be debated. However, as it now stands, the transit work trip model cannot be expected to simulate changes in transit riding with changes in the highway transportation system.

X. INDUCED TRAVEL DEMAND FORECASTING PROCEDURES

Two procedures were developed from the cross-elasticity model for forecasting induced travel. The first is based on vehicle rides and vehicle hours of travel. The second is based on numbers of trips.

A. Induced Travel: Calculated from Vehicle Miles and Hours of Travel

Induced travel is "the added component of traffic volume on a facility which previously did not exist (physically) in any form, but which results when new or improved transportation facilities are provided". [1]

Induced travel can be modelled or described as the additional travel volume resulting from a shift along a fixed demand curve. The shift occurs as the total cost of travel to users is lowered. In Figure 1, the additional (induced) travel is ΔV resulting from a lowering

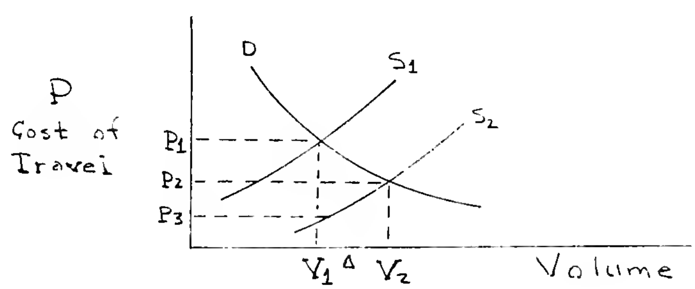


Figure 1: Describing the shift along a Demand Curve.

of the cost of travel from P_1 to P_2. This occurs when travel improvements are made which change the cost performance curve describing the supply of transportation from S_1 to S_2.

BTPR's use of a fixed trip distribution to test alternative transportation improvements holds total travel in the region constant at V_1. V_1 is the total travel between zonal interchanges. The sum of travel on all links in the system

[1] Schmidt, Robert E. and Campbell, M. Earl, Highway Traffic Estimation, The Eno Foundation, Saugatuck Conn., 1956, p. 4.

(in vehicle miles or vehicle hours) can change due to changes in directness and speeds on paths supplied by alternative systems tested. However, the total behavioral travel between origins and destinations, (here represented in the aggregate as V_1), remains a constant/input to, and output of BTPR assignment programs. Nevertheless, BTPR's assignment programs do produce an estimate of the aggregate savings (or changes) in distance and time of travel on all links for any two alternatives tested. The aggregate travel cost savings from one improvement over a lessor improvement (or null alternative) are $P_1 - P_3$ in Figure 1. Note that this quantity is greater than $P_1 - P_2$, the savings in travel costs to users at equilibrium (where cost of travel supplied equals cost of travel demanded). $P_1 - P_3$ can be used to obtain an estimate of ΔV, the induced travel from the user travel cost savings supplied by a new facility. Iterations could be made to update the costs of travel from the addition of ΔV volume to more properly estimate equilibrium volumes at P_2. However, due to the approximations inherent at several steps in the BTPR travel forecasting methodology, iterating is not recommended for use in this method.

The use of $P_1 - P_3$ to estimate induced travel is simply one of several sources of over or underestimation in the method (here overestimation). These sources of error in the method will be explicitly accounted for and are felt to be at least partially compensating. Models are always approximations. The patina of false precision of numbers should be removed and estimates of random variables made instead with the knowledge of their distribution and probable error. Estimates of induced travel would appear to be important to the BTPR for two reasons. The first is that estimates of the additional travel are needed to be able to assess the performance of the proposed transportation system. Will it operate as planned, or does the new travel lead to a system breakdown in some undesirable or otherwise unanticipated way? The second and at least as important reason is that the amount of induced travel is directly related to the additional travel benefit provided by an improved facility. Travel behavior changes (trips are induced) in proportion to service improvements perceived by travelers, and not in proportion to any other characteristics of new transportation facilities. The proposed method for calculating induced travel can differentiate importantly

between alternative transportation improvements, including between those which exhibit barely perceptable transportation service benefits to travelers, and those which show considerable benefits. Since user benefits are normally the primary reason for making transportation improvements, estimates of induced demand can be of considerable help to decisionmakers. The method proposed here translates aggregate system changes between alternatives measured in vehicle miles of travel (VMT) and vehicle hours of travel (VHT) into measures of induced travel and thus user benefit. The induced travel and user benefits can be traced (ceterus parabus) to the one highway improvement which constitutes the system change between assignments. Thus aggregate system totals of VMT and VHT are converted to a single metric, quite useful for evaluation, and the incidence of that metric is linked to a specific highway improvement.

1. BTPR Changes in Travel Costs

The BTPR assignment programs produce estimates of the following changes in highway user travel costs with changes in (line haul) highway links:

(1) savings in line haul travel time, and

(2) changes in auto line haul costs.

The first are produced by average speed increases on improved highway links on which existing vehicles travel, and to which existing O - D flows are diverted. The second are vehicle operating cost changes which result from decreased or increased vehicle mileage on faster, but not necessarily more direct (shorter distance) routes using the new or improved highway links.

2. The Cross Elasticity Model

The cross elasticity model, documented and explored in the previous section, is a direct demand model capable of estimating induced travel. The estimates of highway travel produced by the model are sensitive to the above travel time and cost changes produced by line haul highway improvements. The proposed method makes use of the auto work and auto shop demand elasticities produced

by the model, rather than the full model itself. This avoids the need for computations and data on all the time and cost variables in the model. The result is an incremental sensitivity analysis in the tradition of incremental benefit/cost economic analysis. The additional (induced) regional travel is calculated and ascribed to changes in travel times and costs produced by the single change in the network, namely the proposed additional or improved highway facility.

3. Elasticities

Elasticities of demand with respect to variables affecting demand are convenient summary measures of travel behavior. They are dimensionless quantities denoting the percent change in travel with a one percent change in the variable affecting demand. Elasticity (η) with respect to a variable X is defined mathematically as:

$$\eta_X = \frac{\partial N}{N} \Big/ \frac{\partial X}{X} = \frac{X}{N} \frac{\partial N}{X}$$

where: N is demand

and X is the variable affecting demand.

For purposes of the intended sensitivity analysis, the elasticity of travel demand with respect to a transportation improvement should be independent of the existing level of demand between an origin and destination pair. This allows changes in regional travel to be estimated without having to make estimates of travel for each trip interchange affected by the highway improvement. We are not so fortunate in the case of the cross-elasticity model auto work equation already estimated for the Boston Region. This equation is in log/linear form:

$$\frac{N}{Y} = C + \alpha X + \beta \ln X,$$

resulting in the calculation of the elasticity of $N/_Y$, (travel) with respect to a variable X to be:

$$\eta_X = \frac{X}{N/Y} \frac{\partial N/Y}{\partial X} = \frac{X}{N/Y} \frac{\partial (c + \alpha X + \beta \ln X)}{\partial X}$$

$$= \frac{X}{N/Y} \left(\alpha + \frac{\beta}{X}\right) = \frac{\alpha X + \beta}{N/Y}$$

Thus $N/_Y$ for each O - D pair remains in the work trip elasticity calculations for the X variables, in this case auto line haul time and cost. The proposed method keeps $N/_Y$ constant at its regional mean value used for estimating the cross elasticity model, namely 2.19. This important assumption eliminates the need to compute the value of η for each trip interchange but leads to possible errors which may be discussed as follows. As zones become further apart, they tend to interchange fewer trips, leading to a reduction in $N/_Y$ and an increase in η_X according to the formula. For shorter trips, the opposite occurs. Thus the use of a constant η computed with a mean value of $N/_Y$ results in underprediction of induced travel for longer trips and an overprediction for shorter trips, given a constant percent change in X. Expressways and major new facilities such as the proposed Southwest Expressway and Third Harbor Tunnel tend to be used by longer trips than the regional averages. The assumption of a constant elasticity would tend to produce underestimates of induced travel on these facilities with a constant percent change in X. However, this is offset in part by the fact that in reality the percent change in X between individual zones for a given facility improvement is not constant. As zones become more widely separated, a given facility improvement contributes a smaller percent reduction in travel time and cost of making the interzonal trip. Thus errors are compensating for any given longer or shorter than average trip interchange. Also, since we are interested in computing volumes on links and not estimating volumes on the many separate longer <u>and</u> shorter zonal trip interchanges which contribute trips to the link, the estimate of volume on any given link or set of links will contain estimates with compensating errors in both directions. The net effect of using auto work trip elasticities computed with mean values of $N/_Y$ on induced travel estimates on major links should be slight under (or conservative) estimates.

The auto shop equation of the cross elasticity model is used to produce offpeak estimates of induced travel. This equation is better behaved with respect to

computing elasticities. The equation is a product form model, and is written as follows:

$$N = X^{\alpha} e^{\beta X}$$

resulting in the following calculation of the elasticity of N with respect to a variable X:

$$\eta_X = \frac{X}{N}\frac{\partial N}{\partial X} = \frac{X}{N}\,\frac{\partial\left(X^{\alpha} e^{\beta X}\right)}{\partial X}$$

$$= \frac{X}{N}\left[\alpha X^{\alpha-1} e^{\beta X} + X^{\alpha}\beta e^{\beta X}\right]$$

and since $N = X^{\alpha} e^{\beta X}$, N cancels leaving:

$$\eta_X = \alpha + \beta X$$

This expression omits any term for the number of trips N. However, like the previous expression for auto work, the value of **X** can remain (for non zero values of η).

4. Estimation of Elasticities

Auto Work Trips

X = auto line haul time

$$\eta_X = \frac{\alpha X + \beta}{N/Y}$$

$\alpha = 0$

$\beta = -1.7973$

$\frac{N}{Y} = 2.19$ (mean value)

$$\eta_X = \frac{-1.7973}{2.19}$$

$$= -0.82$$

X = auto line haul cost

$$\eta_X = \frac{-1.0793}{2.19}$$

$$\eta_X = -0.49$$

$\alpha = 0$

$\beta = -1.0793$

$\frac{N}{Y} = 2.19$ (mean value)

Note that the value of X is not included in these values for auto work trip elasticities.

Auto Shop Trips

X = auto line haul time

$$\eta_X = \alpha + \beta X$$

$\alpha = -.081710$

$\beta = -.024824$

$$\eta_X = -.0817 + (-.024824)(37.15)$$

$X_{mean} = 37.15$ min.

$$\eta_X = -1.01$$

X = auto line haul cost

$\alpha = -0.878$

$\beta = 0$

$$\eta_X = -0.878$$

Note that the value of the system variable X appears in the calculation of the shopping η for auto line haul time. The mean value used for estimation of the equation was used in the above calculation. The use of this value is conservative for two reasons. The first is that the auto shop trip sample used for model estimation is likely to have shorter trips than that used for forecasting because of the sample selection procedure. The second reason is (again) that expressway trips tend to be longer than average. Thus the values of X in the forecasts will be somewhat larger on the average than 37.15 minutes. This will result in underestimates of induced travel using the constant value of η_X for auto line haul time above.

5. Description of Method

o. The proposed method involves several easy steps:

Compute the percentage reduction in VHT for the region and the percentage change in VMT for the region. The changes are between assignments with fixed trip distributions for systems with and without the new facility(s) for which estimates of induced travel are desired. The order of testing is important. Logically, the improvement being evaluated should be the "next" system increment over and above (i.e. compared to) that which has already been decided to implement. This cannot always be done, of course, since several system alternatives are being tested at once. However, users of the method should recognize that estimates of induced travel on an improvement will vary as the base system varies. (This, in part, is because of facility interactions). Several assignments may properly be called for in order to carry out incremental benefit cost analysis of several system alternatives.

o. Compute the % increase in regional travel by multiplying the percent changes in VHT and VMT by the elasticities for a auto line haul time and cost respectively, to produce the percent changes in travel due to each variable. The % induced travel will be the algebraic sum of the products. The elasticities to use are a weighted average for work and non work purposes. Shopping is taken as representative of all non work purposes. The weighting calculation follows: 0.36 and 0.64 are the (1963) proportions of work and non work purpose trips respectively.

$$\eta \text{ auto line haul time} = 0.36\ (-0.82) + 0.64\ (-1.01) = -0.94$$

$$\eta \text{ auto line haul cost} = 0.36\ (-.49) + 0.64\ (-0.878) = -.74$$

o. Compute total induced vehicle miles of travel by multiplying the algebraic sum of the percent changes in regional travel due to changes in VMT and VHT, by the total regional VMT.

o. Compute the percent induced travel on the new facility by dividing total induced regional VMT by total VMT on the proposed new facility.

o. An estimate of the average ADT increase across a point on the new facility may be obtained by dividing the total in-

duced VMT by the length of the new facility.

6. Example Calculation: S.W. Corridor

The Southwest corridor of Boston will be used as the site of an example calculations to illustrate the method. The results should be considered very preliminary. The estimates of regional changes in VMT and VHT supplied for these calculations result from more than two different assignments. Two assignments have been used to "build up" estimates of VMT and VHT for a single system which includes everything but a S.W. expressway. Because of facility interactions, these VMT and VHT estimates must be viewed with considerable caution. Better estimates are yet to be provided. The estimates of regional changes in VMT and VHT are between the aforementioned system, and a system (2L) including all (as yet undecided) proposed improvements including the S.W. expressway from Route 128 to the Third Harbor Tunnel. The input data from the assignments are as follows:

Δ VMT = +25,000
Δ VHT = - 2,000
Total VMT = 45,750,000
Total VHT = 1,640,000
VMT on Southwest Expressway = 632,000
Length of Southwest Expressway = 12 miles

The step by step calculation is as follows:

% changes in:

VMT = +25,000   45,750,000 = +.0548%
VHT = - 2,000   1,640,000 = -.122%

% induced travel for region:

due to time: -0.94 (-0.122%) = +.115%

due to cost: - .74 (+0.0548%) = -.0405%

= +.0745%

Total regional induced travel (VMT):

+0.0745% (45,750,000) = +34,000 VMT

% induced travel on S.W. Expressway:

+34,000/632,000 = +5.4%

Typical ADT increase at a point due to induced travel:

$$\frac{\text{34,000 VMT}}{\text{12 mile Expwy.}} = \text{2,830 vehicles}$$

This chould only be regarded as an example calculation. Estimates of regional changes in VMT and VHT between (only) two assignments under somewhat comparable circumstances elsewhere in the region were substantially higher.

7. Discussion of Errors

The method, as noted, ascribes all induced travel in the region to the particular facility improvement in question, (ceterus parabus). However, the improved facility may relieve parallel facilities (e.g. arterials). The following is thus likely to be the reasons for the estimate of induced travel:

- o. Underestimate since the BTPR has not increased speeds on parallel facilities to reflect reduced loadings (i.e. equilibrium speeds).

- o. Overestimates, since the speeds on the new facilities have not been reduced to reflect the decreased equilibrium speeds with the (new) induced travel. Referring

to Figure 1, (P_1 - P_3) has been used, not (P_1 - P_2).

These errors may be considered to be somewhat compensating, with the overestimate perhaps prevailing in this instance.

The aggregate system VMT generated by the BTPR assignment program represents the algebraic sum of many plus and minus changes in distance travelled between i-j pairs as a new or improved facility is added. However, some of the plus distances are incorrect and are brought about by a minumum path algorithm which operates exclusively on travel time.

They are incorrect in those instances when η cost X% Increased distance is greater than η time X% Reduced time. The selection of the longer distance but shorter time path in these cases is incorrect, since we can safely assume that people will not choose a path that makes the trip more onorous. Thus the total change (decrease) in VHT between an alternative and its null case is apt to be the sum exclusively of minuses (since minimun paths switch only for time decreases), but probably a few too many minuses, while the change in VMT will be the algebraic sum of plusses and minuses, with perhaps a few too many plusses. (Since increased distance doesn't affect the minimum path selection). The errors can be considered compensating in this instance.

In conclusion, there are seen to be many compensating errors in this method. However, the overall bias introduced by the errors is regarded as small and within the range of the errors in the models themselves (i.e. errors in measurement of the effect of the system variables by the model in the first place). The major contributing (and compensating) errors are regarded as the underprediction introduced by using average values of $N/_Y$ and X in computing elasticities, and the overprediction by not using equilibrium values of travel costs (i.e. P_2 instead of P_3 in Figure 1).

B. Induced Travel: Calculated from Trip Lengths

An estimate of induced automobile travel demand for the Third Harbor Crossing was prepared using the following procedure. The basic equation for calculation is as follows:

$$\text{Induced auto trips}_{ij} = E\ (\%\ \text{travel time saved}_{ij})\ (\text{auto trips})_{ij})$$

where E is an averaged elasticity coefficient computed from the Charles River Associates (CRA model of travel demand forecasting. It is averaged and weighted by work and non-work components. The computed value of .95 for E was derived as follows:

$$E = (.82)\ (.36) + (1.02)\ (.64)$$

.36 and .64 are the proportions of 24-hour average daily auto travel made up by work and non-work purposes respectively. .82 and 1.02 are published "direct" elasticities of demand for auto travel for work and shopping respectively*. These elasticities are computed for auto in-vehicle travel times. They are the regional mean elasticities. The CRA model actually computes individual elasticities for zonal trip interchanges. Use of the mean elasticities will tend to overestimate small volume trip interchanges and underestimate large volume trip interchanges, resulting in some error cancelling. Since the prime interest is in computing volumes on a link, and not on estimating separate zonal trip interchanges, this procedure is satisfactory, although the estimate produced should be regarded as conservative because the underestimation probably exceeds the overestimations.

* See "Estimation of Urban Passenger Travel Behavior: An Economic Demand Model", by Thomas A. Domencich, Gerald Kraft and Jean-Paul Valette, Highway Research Board Record No. 238, pp. 64-76. The shopping elasticity represents all non-work travel in this analysis.

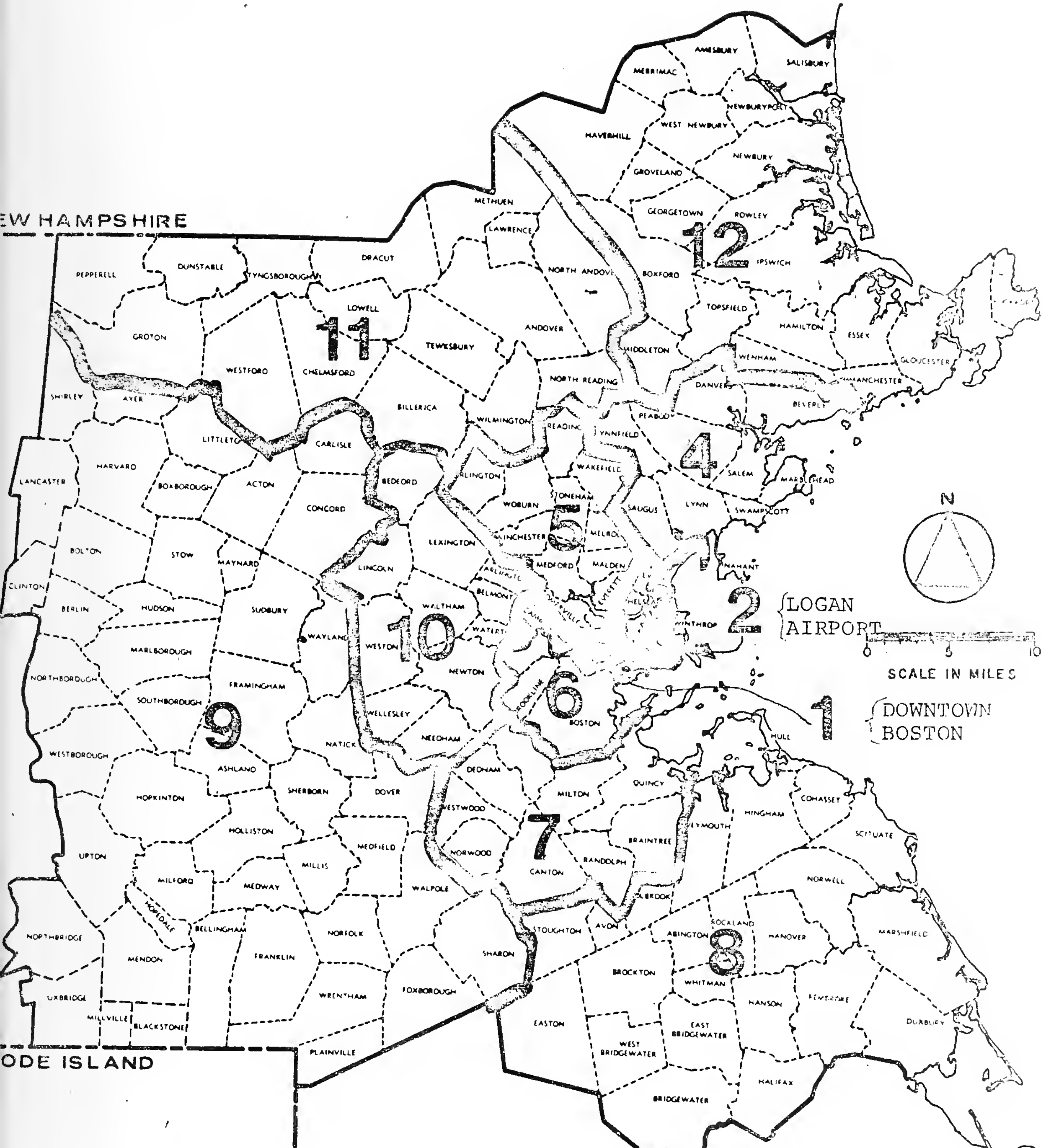
The EMRPP 152 city and town region was divided into 12 districts. From a 12 X 12 trip matrix, the interchanges requiring a harbor crossing were identified. 23 such interchanges were identified and averaged zone to zone auto in-vehicle travel times were calculated from the BTPR no-build network.

The difference in travel time for these 23 zonal interchanges with and without a Third Harbor Crossing was calculated. It is determined to be a 4 minute time savings for all non-Logan Airport trips. A 5 minute time savings results for Logan Airport trips because the BTPR alignment for the Third Harbor Crossing goes fairly directly to the airport terminal area.

An estimate of district-to-district automobile trips without the new facility is the third data item required. This was calculated from selected link assignments (for the Sumner-Callahan Tunnels and Tobin Bridge) of automobiles to the no-build networks, and from the district-to-district trip table for the 12 districts. The selected link information helped to identify how many of the projected trips between the 23 pairs of districts would actually desire to cross the harbor. The number estimated by this procedure is 106,700 which includes 66,200 automobiles assigned to the Sumner-Callahan Tunnels and 40,500 automobiles assigned to the Tobin Bridge. An additional 23,500 automobiles assigned to the Tobin Bridge were not considered candidates for estimating the "base" from which Third Harbor Crossing induced auto trips would be derived. That is, these were not considered to be trips for which a Third Harbor Crossing would offer any time savings.

The "induced" number of auto trips calculated for 1980 with this procedure is 8,627. Data for the calculation are appended. Increasing the volume by 5% for trucks yields 9,058. The estimate may be considered the first year of operation figure. It may be considered a conservative figure for the reason cited above.

No other new facilities except the Third Harbor Crossing and its immediate approaches were considered in the analysis. If additional linked facilities such as I-95 Relocated, I-95 from Cutler Circle to Route 128 and the Southwest Expressway are considered, auto travel time savings will be further increased and induced auto trips will be increased.



TWELVE DISTRICT SYSTEM FOR CALCULATING

HARBOR CROSSING INDUCED TRIPS

CALCULATIONS FOR INDUCED AUTO TRIPS IN A THIRD HARBOR CROSSING

(1) Zonal Interchange	(2) No-Build Travel Time (minutes)	(3) Minutes Saved by 3rd Harbor Crossing	(4) $\frac{(3)}{(2)}$	(5) (3) x .95	(6) 1980 Auto Trips	(7) (6) x (5)
1-2	18	5	.278	.264	700	185
1-3	22	4	.182	.173	1,300	225
1-4	40	4	.100	.095	1,100	105
1-12	55	4	.073	.069	600	41
2-6	32	5	.156	.148	7,000	1,036
2-7	47	5	.106	.101	5,526	558
2-8	67	5	.075	.071	7,221	513
2-9	81	5	.062	.059	13,000	767
2-10	47	5	.106	.101	7,000	707
3-6	34	4	.118	.112	12,000	1,344
3-7	52	4	.077	.073	4,105	300
3-8	64	4	.063	.060	2,425	146
3-9	76	4	.053	.050	1,800	90
3-10	46	4	.087	.083	2,600	216
4-6	55	4	.073	.069	13,000	897
4-7	71	4	.056	.053	2,215	117
4-8	83	4	.048	.046	2,598	102
4-9	90	4	.044	.042	3,200	109
5-7	53	4	.075	.071	6,500	227
5-8	70	4	.057	.054	6,500	351
6-12	66	4	.061	.058	5,000	290
7-12	83	4	.048	.046	2,000	92
8-12	105	4	.038	.036	5,811	209
Total	-	-	-	-	106,701	8,627

APPENDIX A

STUDY ELEMENT 6 WORKING PAPERS

DATE	FILE	FROM	SUBJECT/TITLE
9/7/71	B.2	B. Barber	Population and Employment Adjustments for Task A
9/15/71	B.3.6	D. Brand	Work Program for the Use of the Cross-Elasticity/Dodotrans Models in Phases I and II of the Restudy
9/22/71	B.3.0	B. Barber	Trip Tables Available Now (from previous studies)
9/24/71	B.3.4	J. Brevard	Regional Traffic Data
10/22/71	B.3.6	B. Barber	Future Population Estimates for Cities and Towns in the BTPR Region
11/11/71	B.3.6	B. Barber	Employment Forecasts
11/22/71	B.3.11	T. Harrison	Revised Population and Employment Projections for BTPR c Series
11/30/71	B.3.6	B. Barber	Display and Analysis of EMRPP and TASK A Travel Forecasts
12/20/71	B.3.6.	J. McMann	Configuration of Interstate 93/695
12/23/71	B.3.6.	B. Barber	1970 U.S. census Data by Black Group
1/1/72	B.3.6.	D. Brand	Analysis and Appraisal of the Cross-Elasticity Model for Use in Boston Transportation Planning Review's Phase II
1/3/72	B.3.6.	Systems Analysis Group	1973 Base Highway Network
1/4/72	B.3.7.	J. Brevard	Status of PMM Selected Link Output
1/5/72	B.3.6.	D. Brand	Coding Conventions, Instructions and Data Ranges for Use in the 1963 Test of the Cross-Elasticity Model - BTPR

DATE	FILE	FROM	SUBJECT/TITLE
1/10/72	B.3.6.	J. McMann	Highway Alternatives in the First Round Network Analyses
1/10/72	B.3.6.	Systems Analysis Group	Traffic Forecasting Methods. . . First Round Highway Forecasts
1/11/72	B.3.6.	B. Barber	Creation of Trip Tables for Phase II Analysis
1/25/72	B.4.6.	B. Barber	Discussion of Current Ground Travel Forecasts for Logan Airport with Implications for Boston Harbor Crossings
1/26/72	B.3.6.	B. Barber	Fourth Count 1970 U.S. Census Information
2/3/72	B.3.6.	M. West	Highway Issues to be Addressed in the First Round Network Analysis
2/21/72	B.3.6.	B. Barber	Changes in Travel Time by Private car over Major Radial Routes to Downtown Boston
2/29/72	B.3.6.	B. Barber	Accessibility Measurements of Transportation Impacts
3/3/72	B.3.6.	B. Barber	Population Capacities of Vacant Developable Land in the Inner Suburbs
3/7/72	B.5.11.	B.Barber	Background on the EMPRIRC Model Prediction of Low Income Families
3/16/72	B.3.6.	M. West	Reiteration of Highway Alternatives to be Tested in the First Round Network Analysis
4/7/72	B.4.6.	M. Fistel	Traffic Volumes and Turning Movements for the North Shore
4/24/72	B.3.6.	B. Barber	A Small Area Model for Planners
5/8/72	B.1.5.3.	B. Barber	Sumner-Callahan Tunnel Travel to Logan Airport
5/9/72	B.3.6.	O. Wong	Modification of Person Trips
5/15/72	B.3.6.	J. McMann	Direct Demand Model Software
5/19/72	B.3.6.	J. Peers	Additional Work Program Needed to Respond to Rapid Transit Line Between Mattapan and Somerville

DATE	FILE	FROM	SUBJECT/TITLE
5/26/72	B.0.5.2.	J. McMann	CRA Direct Demand Model
6/13/72	B.0.5.3.	J. Peers	Southwest Corridor Systems Analysis Work Program
6/15/72	B.0.5.2.	J. Peers and J. McMann	Traffic Analysis Models
6/16/72	B.3.6.	J. Peers	I-95 Relocated
6/16/72	B.3.6.	J. Peers	Transit Output From Systems
6/17/72	B.3.6.	B. Barber	The Procedure to Calculate Induced Auto Trip Demand in the Third Harbor Crossing
6/29/72	B.2.1.6.	J. Peers	Third Harbor Crossing . . . Financial Questions
7/10/72	B.0.5.1.	B. Barber	Allocation of Population and Employment to Analysis Rings for Two Future Land Use Alternatives
7/20/72	B.3.6.	F. Wagner	Demand Delay Analysis of the Sumner-Callahan Tunnels
7/20/72	B.3.6.	D. Brand	Calculating Induced Highway Travel Using BTPR Assignment Program Output; with Example Calculations for the Southwest Expressway
8/3/72	B.0.5.	B. Barber	U. S. Census Fourth Count Data for 1970 Population
8/21/72	B.1.5.3.	B. Barber	Bus/Limousine Service to Logan Airport
10/12/72	B.0.5.2.	J. McMann	BTPR Mode Split Model
10/17/72	B.0.5.	D. Brand	Report on Investigations and Use of the Cross-Elasticity Travel Forecasting Model for the BTPR and Options for its Further Use
10/17/72	B.0.5.2.	J. McMann	The n-Dimensional Logit Function Made Simple
10/23/72	B.0.5.	J. McMann	The R^2 Statistic Made Simple, or the Last Word on R^2

APPENDIX B

STUDY ELEMENT SIX MATERIAL IN BTPR FINAL REPORTS

Report	Material/Title	Pages
North Shore	Key Questions	I-7
" "	North Shore Transportation Problems	I-8 to I-10
" "	Transportation System Inter-relations	I- 5 to I-19
" "	Transportation and Alternative Shapes of the Future	I-35 to I-38
" "	Projected North Shore Population, Employment and Travel Demands	I-65 to I-72
" "	1980-2000 Travel Volumes - Alternative 1A	II-37
" "	" " " " " 1B	II-55
" "	" " " " " 2	II-71
" "	" " " " " 3	II-91
" "	" " " " " 4	II-102
" "	Transportation Service and Evaluation Criteria	II-111 to II-117
" "	Incidence of Costs and Benefits	II-228
" "	Transit in the North Shore	III-1 to III-58
I-95 Relocated/ Revere Beach Connector	Transportation Implications of Alternative Program Packages	IV-24 to IV-27
"	Impact of I-95 Relocated on Ridership of the Blue Line	IV-30
"	Incidence of Costs and Benefits	IV-31
"	Transportation Context	IV-51 to IV-56
"	Traffic Volumes - Alternative 1	IV-71
"	" " " 2	IV-82
"	" " " 3	IV-95
"	" " " 4	IV-106
"	" " " 5	IV-118
"	" " " 6	IV-125
"	Transportation Service	IV-175 to IV-178

Report	Material/Title	Pages
Southwest Corridor	Summary Transportation Service Evaluation	S-21 to S-27
"	Key Questions	I-7
"	Southwest Transportation Questions	I-8 to I-12
"	Projected Southwest Population, Employment and General Travel Demands	I-76 to I-88
"	Transportation System Inter-relationships	I-89 to I-102
"	Highway Travel Problems in the Southwest	II-10 to II-14
"	1980-1995 Traffic Volumes - Alternative 1	II-29
"	" " " " " 2A	II-55
"	" " " " " 2C	II-86
"	Southwest Transit: Deficiencies and Issues	III-11 to III-22
"	Evaluation of Moderate and Maximum Versus Existing Transit Investment	III-35 to III-42
"	Transportation Service	IV-105 to IV-113
Harbor Crossing	Major Transportation Problems and Conditions	22 to 23
" "	Transportation Implications of Alternative Program Package Elements	31 to 57
" "	Traffic Estimates	112 to 115
" "	Transportation Service	167 to 170

APPENDIX C

General Socio-Economic Data by Community Used in S.E.G.

(All Data in Thousands)

Population

Community	1960	1970	1980 I*	1980 II*	1995 I
E. Boston	42.9	38.9	36.5	38.0	35.0
Charleston	20.1	15.4	16.5	19.0	17.8
Downtown	52.4	54.3	60.0	77.0	60.0
South End	31.3	21.7	21.7	26.0	21.7
" Boston	45.8	38.5	37.0	42.0	35.8
N. Dorchester	97.0	90.8	88.0	92.0	86.0
S. "	31.3	26.2	27.0	28.0	28.0
Mattapan	33.7	33.5	34.0	35.0	35.3
Roslindale	26.5	28.2	28.0	28.0	28.0
J. Plain	23.0	23.6	49.0	50.0	49.0
Roxbury	87.1	63.3	63.3	65.0	63.3
Fenway	67.8	62.2.	36.7.	40.0	35.0
Brighton	64.3	63.7	56.5	59.0	49.2
Brookline	54.0	58.9	61.5	65.0	64.0
Cambridge	107 7	100.4	93.0	103.0	88.0
Somerville	94.7	88.8	82.0	90.0	77.0
Everett	43.5	42.5	42.0	46.0	41.5
Chelsea	33.7	30.6	28.0	32.0	25.0
Lynn	94.5	90.3	89.5	93.0	87.4
Saugus	20.7	25.1	29.0	28.0	34.0
Revere	40.1	43.2	44.5	47.0	48.0
Winthrop	20.3	20.3	21.0	22.0	22.5
Malden	57.7	56.1	52.5	56.0	49.0
Melrose	29.6	33.2	33.0	35.0	33.8
Winchester	19.4	22.3	23.5	25.0	25.0
Medford	65.0	64.4	65.5	68.4	67.0
Arlington	50.0	53.5	54.0	58.0	56.0
Belmont	28.7	28.3	29.0	30.3	33.0
Watertown	39.1	39.3	40.5	41.0	40.0
Newton	92.4	91.1	93.0	98.5	95.0
W. Roxbury	19.5	25.0	25.0	27.0	25.0
Hyde Park	43.0	49.5	50.5	50.0	52.0
Milton	26.4	27.2	29.0	39.2	32.0
Quincy	87.4	88.0	90.0	95.0	92.0
Braintree	31.1	35.1	41.5	39.8	48.0
Weymouth	48.2	59.6	58.5	56.5	62.0
Randolph	18.9	27.0	35.0	33.5	41.5
Canton	12.8	17.1	23.6	23.0	30.0
Norwood	24.9	30.8	39.0	32.0	38.0
Westwood	10.4	12.8	16.0	14.0	20.0
Dedham	23.9	26.9	27.5	28.0	28.0
Needham	25.8	29.7	32.0	32.0	35.0
Wellesley	26.1	28.1	31.9	30.0	35.0

*I = Existing Trends Extended, II = Core Intensive Alternative

Community	Population 1960	1970	1980 I*	1980 II*	1995 I
Weston	8.3	10.9	19.0	12.7	28.0
Waltham	55.4	61.6	64.0	63.0	66.0
Lexington	27.7	31.9	40.0	38.0	50.0
Burlington	12.9	22.0	30.0	26.0	39.0
Woburn	31.2	37.4	46.0	41.0	50.5
Stoneham	17.8	20.7	23.5	22.0	26.3
Reading	19.3	22.5	30.0	25.0	35.0
Wakefield	24.3	25.4	28.5	27.0	31.5
Lynnfield	8.4	10.8	13.2	12.5	16.0
Peabody	32.2	48.1	55.5	51.0	62.9
Danvers	21.9	26.2	30.5	28.0	35.0
Beverly	36.1	38.3	46.5	46.5	55.0
Salem	39.2	40.6	41.5	45.0	43.0
Marblehead	18.5	21.3	24.5	23.0	28.4
Swampscott	13.3	13.6	14.9	15.0	16.0
Nahant	4.0	4.1	4.8	4.2	5.9
Rockport	4.6	5.6	9.5	6.5	8.0
Gloucester	25.8	27.9	30.0	28.5	33.0
Manchester	3.9	5.2	6.5	5.7	8.0
Essex	2.2	2.7	3.8	3.0	5.2
Ipswich	8.5	10.8	13.0	12.5	15.4
Hamilton	5.5	6.4	8.5	8.0	10.5
Wenham	2.8	3.8	4.8	4.5	6.2
Topsfield	3.4	5.2	7.3	7.0	9.3
Middleton	3.7	4.0	6.0	5.5	7.8
N. Reading	8.3	11.3	15.0	14.0	18.0
Wilmington	12.5	17.1	23.5	19.0	30.0
Billerica	17.9	31.6	41.0	35.0	49.0
Carlisle	1.5	2.9	3.9	3.4	5.8
Bedford	11.0	13.5	17.0	14.5	21.0
Concord	12.6	16.1	23.5	18.0	31.5
Lincoln	5.6	7.6	9.5	8.5	11.5
Wayland	10.4	13.5	19.5	15.0	26.0
Sudbury	7.4	13.5	24.5	16.0	6.0
Framingham	44.5	64.0	68.0	67.0	72.0
Natick	28.8	31.1	34.0	33.0	37.0
Sherborn	1.8	3.3	6.0	5.0	9.0
Dover	2.8	4.5	7.5	6.5	9.0
Medfield	6.0	9.8	12.5	11.5	15.5
Walpole	14.1	18.1	21.5	20.0	25.0
Foxboro	10.1	14.2	18.7	16.0	21.0
Sharon	10.0	12.4	16.0	14.0	18.0
Stoughton	16.3	23.5	30.0	26.0	37.5
Avon	4.3	5.3	7.0	6.0	8.6
Holbrook	10.1	11.8	14.0	13.0	17.5

*I = Existing Trends Extended, II = Core Intensive Alternative

APPENDIX C

General Socio-Economic Data by Community Used in S.E.G.

(All Data in Thousands)

	Employment				
Community	1963	1969	1980 I	1980 II	1995 I
E. Boston	5.2	11.5	14.0	18.0	16.0
Charleston	16.9	15.5	15.0	20.0	16.0
Downtown	234.1	250.0	268.0	304.0	282.0
South End	12.2	13.0	17.0	22.0	18.0
" Boston	37.7	46.7	50.5	65.0	51.0
N. Dorchester	11.0	15.0	16.0	30.0	17.0
S. "	4.1	4.5	4.8	8.0	5.0
Mattapan	4.0	4.0	4.0	6.0	4.0
Roslindale	2.8	3.5	3.8	6.0	4.0
J. Plain	6.9	8.0	8.3	12.0	8.5
Roxbury	13.4	14.5	16.0	22.0	18.0
Fenway	39.7	43.5	44.5	52.0	45.5
Brighton	17.7	23.5	21.2	35.0	24.0
Brookline	14.3	14.8	18.5	20.0	20.0
Cambridge	80.7	86.9	93.0	98.0	100.0
Somerville	21.6	23.9	28.0	30.0	35.0
Everett	13.5	13.4	13.5	15.0	14.0
Chelsea	12.2	13.4	12.5	14.0	14.0
Lynn	35.6	36.6	37.5	41.0	40.0
Saugus	4.7	7.6	8.7	9.5	10.0
Revere	5.8	7.7	8.0	8.7	8.5
Winthrop	1.7	1.6	1.5	1.8	1.8
Malden	17.5	18.5	20.5	21.0	20.0
Melrose	4.4	7.7	8.5	8.5	8.0
Winchester	5.0	3.3	5.5	5.5	7.5
Medford	15.0	13.7	16.5	17.0	18.0
Arlington	6.8	5.9	8.0	8.5	10.0
Belmont	5.5	4.5	5.0	5.5	5.5
Watertown	22.6	19.3	22.0	24.0	23.0
Newton	30.6	30.4	35.5	36.0	36.0
W. Roxbury	1.9	2.5	2.8	3.5	3.0
Hyde Park	5.1	5.5	6.3	7.0	7.0
Milton	3.5	5.3	6.5	6.5	8.0
Quincy	30.5	45.1	50.5	53.0	50.0
Braintree	9.9	18.5	20.5	19.5	21.0
Weymouth	6.8	7.8	13.0	9.4	16.0
Randolph	3.1	6.8	6.5	6.5	6.5
Canton	5.0	7.9	10.0	9.5	12.5
Norwood	11.2	13.9	14.0	14.5	15.0
Westwood	1.7	2.7	4.0	3.5	6.5
Dedham	8.3	13.6	12.5	13.2	14.0
Needham	12.0	15.7	16.0	16.0	16.5
Wellesley	6.6	9.3	12.0	10.7	12.5

*I = Existing Trends Extended, II = Core Intensive Alternative

Employment

Community	1963	1969	1980 I	1980 II	1990 I
Weston	3.1	2.1	5.0	3.0	10.0
Waltham	39.3	54.6	56.0	56.5	60.0
Lexington	4.8	9.1	12.0	11.0	15.0
Burlington	7.4	21.8	22.0	23.0	23.0
Woburn	8.9	12.1	18.5	16.0	25.0
Stoneham	2.5	4.7	5.5	5.0	5.5
Reading	2.9	4.1	6.5	5.5	8.0
Wakefield	7.8	11.3	11.0	11.5	11.0
Lynnfield	1.4	1.7	3.5	2.0	5.0
Peabody	11.2	16.6	18.0	17.5	23.0
Danvers	6.1	9.8	13.0	11.0	17.0
Beverly	11.1	11.7	13.5	12.0	15.0
Salem	19.2	19.1	20.5	22.0	22.0
Marblehead	2.3	2.6	2.7	2.7	3.0
Swampscott	1.7	1.7	1.8	1.7	2.0
Nahant	.2	.3	.4	.3	0.5
Rockport	.9	1.2	1.5	1.3	1.7
Gloucester	8.5	8.3	10.5	9.0	11.0
Manchester	.5	.6	1.5	1.0	2.0
Essex	.4	.5	1.1	.9	1.5
Ipswich	1.8	2.6	4.0	3.0	4.7
Hamilton	.6	.5	1.5	.8	2.0
Wenham	.2	.3	1.3	.5	1.5
Topsfield	.4	.5	2.8	.8	3.5
Middleton	.4	.9	2.8	1.0	4.3
N. Reading	1.0	1.3	2.5	2.0	3.0
Wilmington	6.1	10.1	12.0	11.2	13.0
Billerica	4.4	4.4	11.0	5.1	15.0
Carlisle	.2	.4	.5	.5	0.6
Bedford	15.2	15.5	15.0	16.0	16.0
Concord	4.9	6.0	5.5	6.0	15.0
Lincoln	.5	.4	1.5	1.0	2.9
Wayland	3.3	6.8	7.0	7.0	8.0
Sudbury	2.6	4.3	6.0	5.0	11.0
Framingham	21.3	31.0	35.5	34.0	36.0
Natick	10.0	13.0	20.5	14.0	25.0
Sherborn	.1	.2	.2	.2	1.5
Dover	.4	.3	2.5	1.0	4.0
Medfield	1.5	1.0	2.5	1.5	2.8
Walpole	6.0	7.1	10.0	8.0	13.0
Foxboro	4.2	6.1	8.0	7.0	10.0
Sharon	.7	1.6	4.0	2.5	6.5
Stoughton	3.8	4.8	8.5	6.0	11.0
Avon	1.3	2.2	3.5	3.0	4.0
Holbrook	1.3	2.2	3.0	2.4	3.5

*I = Existing Trends Extended, II = Core Intensive Alternative

APPENDIX C

General Socio-Economic Data by Community Used in S.E.G.

(All Data in Thousands)

Automobiles

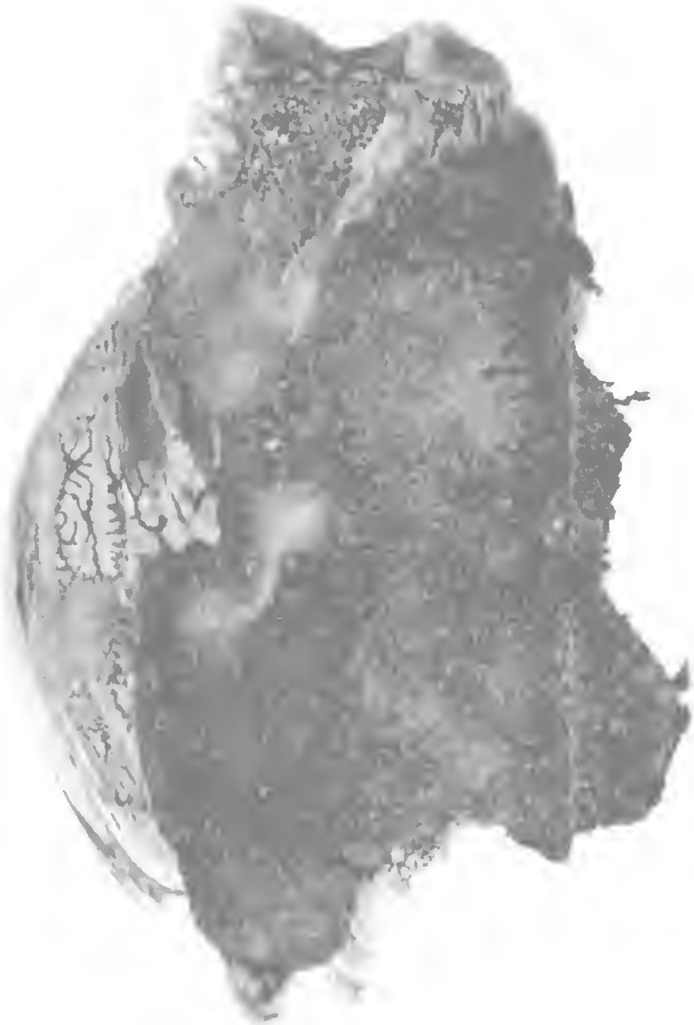
Community	1963	1980 I	1980 II	1995 I
E. Boston	8.0	10.0	11.0	16.8
Charleston	3.0	4.5	5.0	8.5
Downtown	9.9	11.0	14.0	12.8
South End	3.7	4.0	6.0	11.3
" Boston	6.3	10.0	12.0	17.2
N. Dorchester	17.4	25.0	27.0	41.3
S. "	7.8	11.0	12.0	13.4
Mattapan	8.4	12.0	13.0	18.4
Roslindale	7.9	12.0	13.0	14.6
J. Plain	12.3	18.5	19.0	25.5
Roxbury	12.1	18.0	20.0	30.4
Fenway	8.1	10.0	12.0	18.2
Brighton	16.2	20.0	22.0	25.6
Brookline	18.0	24.0	25.0	35.8
Cambridge	24.5	33.0	34.0	44.2
Somerville	21.0	29.0	30.0	36.0
Everett	11.4	15.0	16.0	19.9
Chelsea	7.2	10.5	11.0	12.0
Lynn	24.8	32.0	33.0	43.3
Saugus	7.9	11.5	12.0	17.7
Revere	10.5	16.0	17.0	25.5
Winthrop	5.2	8.5	9.0	11.7
Malden	14.8	19.5	20.0	25.4
Melrose	10.7	12.5	13.0	17.6
Winchester	8.4	9.5	10.0	14.0
Medford	18.0	24.0	26.0	35.4
Arlington	17.4	21.0	22.0	29.6
Belmont	10.8	13.0	14.0	18.5
Watertown	12.3	15.5	16.0	20.8
Newton	33:7	40.0	42.0	53.8
W. Roxbury	5.8	9.0	10.0	13.0
Hyde Park	9.7	15.5	20.0	27.0
Milton	11.1	12.5	16.0	17.9
Quincy	27.0	32.0	33.0	48.9
Braintree	11.3	16.0	15.0	25.0
Weymouth	16.9	22.0	21.0	32.2
Randolph	6.6	12.0	11.0	21.6
Canton	4.7	9.5	9.0	16.8
Norwood	9.8	13.5	12.0	19.8
Westwood	4.8	6.5	6.0	11.2
Dedham	9.1	11.5	11.0	11.5
Needham	11.5	14.0	13.0	19.6
Wellesley	11.7	14.0	12.0	19.6

*I = Existing Trends Extended, II = Core Intensive Alternative

Automobiles

Community	1963	1980 I	1980 II	1995 I
Weston	4.2	8.0	5.0	15.7
Waltham	16.5	24.5	23.0	38.9
Lexington	11.3	16.0	15.0	28.0
Burlington	5.5	11.0	10.0	21.8
Woburn	11.0	16.0	15.0	27.0
Stoneham	6.9	9.0	8.0	13.7
Reading	7.6	12.0	10.0	20.2
Wakefield	8.6	10.5	10.0	16.6
Lynnfield	4.3	5.5	5.0	9.0
Peabody	14.1	22.0	20.0	32.7
Danvers	8.1	12.0	11.0	18.7
Beverly	12.7	18.5	18.5	28.6
Salem	12.6	16.5	16.5	22.9
Marblehead	8.7	10.0	9.0	15.9
Swampscott	5.5	6.0	6.0	9.0
Nahant	1.6	2.0	2.0	3.4
Rockport	1.8	3.0	2.0	4.5
Gloucester	7.1	11.5	10.0	17.7
Manchester	1.7	2.5	2.2	4.5
Essex	0.7	1.5	1.0	2.9
Ipswich	2.8	5.0	4.0	8.0
Hamilton	2.5	3.5	3.0	5.9
Wenham	1.3	2.0	2.0	3.5
Topsfield	1.2	3.0	3.0	4.8
Middleton	1.3	2.5	2.0	4.2
N. Reading	3.7	6.0	5.0	10.1
Wilnington	4.5	9.5	7.0	16.8
Billerica	6.4	16.5	13.0	25.5
Carlisle	.8	2.0	1.0	3.2
Bedford	4.0	6.8	6.0	6.8
Concord	5.8	9.5	7.0	9.5
Lincoln	2.0	4.0	3.0	6.4
Wayland	5.1	8.0	6.0	15.6
Sudbury	4.0	10.0	6.0	19.9
Framingham	17.8	27.0	27.0	37.4
Natick	11.3	13.5	13.0	19.2
Sherborn	1.0	2.4	2.0	3.7
Dover	2.8	4.5	3.0	5.0
Medfield	2.4	5.0	4.5	8.7
Walpole	2.8	7.0	6.0	13.0
Foxboro	3.2	7.5	5.5	10.9
Sharon	4.2	6.5	5.0	10.1
Stoughton	6.2	10.5	9.0	15.2
Avon	1.5	2.8	2.5	4.1
Holbrook	3.5	4.6	4.0	5.9

*I = Existing Trends Extended, II = Core Intensive Alternative



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